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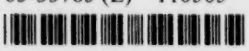

Table of contents

Executive Summary **4**
Overview of options 5
Overarching issues 8
Multilateral nuclear approaches: the future 11
Five suggested approaches 12
Chapter 1 - Foreword **14**
Background 14
Mandate 15
Preliminary Considerations 16
Chapter 2 - Current Political Context **18**
Chapter 3 - Historical Perspective **21**
Chapter 4 - Cross-cutting factors **24**
4.1 - Advances in nuclear technologies 24
4.2 - Economics 26
4.3 - Assurances of supply 27
4.4 - Legal and Institutional 30
4.5 - Non-proliferation and security factors 33
Chapter 5 - Multilateral options for technologies **36**
5.1 - Elements of assessment *37*
Key Elements 37
Other Elements 38
5.2 - Uranium enrichment *40*
Technologies 40
Historical background 42
Current status 43
Economics 45
Assurance of services 45
Legal and institutional 45
Non-proliferation and security 46
Options for multilateral approaches for enrichment 47
5.3 - Spent fuel reprocessing *51*
Technologies 51
Historical background 52
Current status 53
Economics 55
Assurance of services 56
Legal and institutional 56
Non-proliferation and security 57

Options for multilateral approaches for reprocessing 58
5.4 - Spent fuel repositories (final disposal) *62*
Technologies 62
Historical background 62
Current status 63
Economics 64
Assurance of services 66
Legal and institutional 66
Non-proliferation and security 67
Options for final repositories of spent fuel 68
5.5 - Spent fuel storage (intermediate) *72*
Technologies 72
Historical background 72
Current status 72
Economics 73
Assurance of services 73
Legal and institutional 74
Non-proliferation and security 75
Options for multilateral spent fuel storage 75
5.6 - Overview of options *80*
Uranium enrichment 80
Reprocessing 81
Spent fuel disposal 81
Fuel storage 82
Combined option: fuel-leasing/fuel take-back 82
Other options 83
Chapter 6 - Overarching issues 84
Relevant articles of the NPT 84
Safeguards and export controls 85
Voluntary participation in MNAs versus a binding norm 86
Nuclear-weapon States and non-NPT States 87
Breakout and other risks 87
Enforcement 88
Chapter 7 - Multilateral nuclear approaches: the future 89
Five suggested approaches 90
Annex 1 – Letter from the Director General 92
Annex 2 - Participants and contributors 94
Expert Group members 94
Advisors 98
IAEA support 98
External support 98
Annex 3 - Acronyms 99

Multilateral Nuclear Approaches (MNAs)

Executive Summary

22 February 2005

1. The global nuclear non-proliferation regime has been successful in limiting, albeit not entirely preventing, the further spread of nuclear weapons. The vast majority of States have legally pledged to forego the manufacture and acquisition of nuclear weapons and have abided by that commitment. Nonetheless, the past few years have been a tumultuous and difficult period.

2. The decades long nuclear non-proliferation effort is under threat: from regional arms races; from actions by non-nuclear weapon States (NNWS) that have been found to be in fundamental breach of, or in non-compliance with their safeguards agreement, and which have not taken full corrective measures; from the incomplete manner in which export controls required by the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) have been applied; from burgeoning and alarmingly well-organised nuclear supply networks; and from the increasing risk of acquisition of nuclear or other radioactive materials by terrorist and other non-State entities.

3. A different significant factor is that the civilian nuclear industry appears to be poised for worldwide expansion. Rapidly growing global demand for electricity, the uncertainty of supply and price of natural gas, soaring prices for oil, concerns about air pollution and the immense challenge of lowering greenhouse gas emissions, are all forcing a fresh look at nuclear power. As the technical and organisational foundations of nuclear safety improve, there is increasing confidence in the safety of nuclear power plants. In light of existing, new and reawakened interest in many regions of the world, the prospect of new nuclear power stations on a large scale is therefore real. A greater number of States will consider developing their own fuel cycle facilities and nuclear know-how, and will seek assurances of supply in materials, services and technologies.

4. In response to the growing emphasis being placed on international cooperation to cope with non-proliferation and security concerns, the Director General of the International Atomic Energy Agency (IAEA), Mohamed ElBaradei, appointed in June 2004 an international group of experts (participating in their personal capacity) to consider possible multilateral approaches to the civilian nuclear fuel cycle.

5. The mandate of the Expert Group was three-fold:

- To identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;
- To provide an overview of the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and
- To provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the expert group.

6. Two primary deciding factors dominate all assessments of multilateral nuclear approaches, namely "**Assurance of non-proliferation**" and "**Assurance of supply and services**". Both are recognised overall objectives for governments and for the NPT community. In practice, each of these two objectives can seldom be achieved fully on its own. History has shown that it is even more difficult to find an optimum arrangement that will satisfy both objectives at the same time. As a matter of fact, multilateral approaches could be a way to satisfy both objectives.

7. The non-proliferation value of a multilateral arrangement is measured by the various proliferation risks associated with a nuclear facility, whether national or multilateral. These risks include the diversion of materials from an MNA (reduced through the presence of a multinational team), the theft of fissile materials, the diffusion of proscribed or sensitive technologies from MNAs to unauthorised entities, the development of clandestine parallel programmes and the breakout scenario. The latter refers to the case of the host country "breaking out", for example, by expelling multinational staff, withdrawing from the NPT (and thereby terminating its safeguards agreement), and operating the multilateral facility without international control.

8. The "Assurance of supply" value of a multilateral arrangement is measured by the associated incentives, such as the guarantees provided by suppliers, governments and international organisations; the economic benefits that would be gained by countries participating in multilateral arrangements, and the better political and public acceptance for such nuclear projects. One of the most critical steps is to devise effective mechanisms for assurances of supply of material and services, which are commercially competitive, free of monopolies and free of political constraints. Effective assurances of supply would have to include back-up sources of supply in the event that an MNA supplier is unable to provide the required material or services.

Overview of options

9. Whether for uranium enrichment, spent fuel reprocessing, or spent fuel disposal and storage, **multilateral options** span the entire field between existing market mechanisms and a complete co-ownership of fuel cycle facilities. The following pattern reflects this diversity:

Type I: Assurances of services not involving ownership of facilities.

a) Suppliers provide additional assurances of supply;
b) International consortia of governments broaden the assurances;
c) IAEA-related arrangements provide even broader assurances.

Type II: Conversion of existing national facilities to multinational facilities.

Type III: Construction of new joint facilities.

10. On the basis of this pattern, the Group has reviewed the pros and cons associated with each type and option. Pros and cons were defined relative to a "non-MNA choice", namely that of a national facility under current safeguards.

Uranium enrichment

11. A healthy market exists at the front end of the fuel cycle. In the course of only two years, a nuclear power plant operating in Finland has bought uranium originating from mines in seven different countries. For example, conversion has been done in three different countries. Enrichment services have been bought from three different companies. Therefore, the legitimate

objective of assurances of supply can be fulfilled to a large extent by the market. Nevertheless, this assessment may not be valid for all countries that have concerns about assurances of supply. Mechanisms or measures, under which existing suppliers or international consortia of governments or IAEA-related arrangements may be appropriate in such cases.

12. At first, *suppliers* could provide additional assurances of supply. This would correspond to enrichment plant operators, individually or collectively, guaranteeing to provide enrichment capacity to a State whose government had in turn agreed to forego building its own capacity, but which then found itself denied service by its intended enrichment provider for unspecified reasons. The pros include the avoidance of know-how dissemination, the reliance on a well-functioning market and the ease of implementation. The cons refer for example to the cost of maintaining idle capacity on reserve, and the lack of perceived diversity on the supplier side.

13. At a second level, international *consortia of governments* could step in, that is they would guarantee access to enrichment services, the suppliers being simply executive agents. The arrangement would be a kind of "intergovernmental fuel bank", e.g. a contract under which a government would buy guaranteed capacity under specified circumstances. Different States might use different mechanisms. Most pros and cons are shared with the preceding case.

14. Then, there are *IAEA-related arrangements*, a variation of the preceding option, with the IAEA acting as the anchor of the arrangement. Essentially, the Agency would function as a kind of "guarantor" of supply to States in good standing and that were willing to accept the requisite conditionality (which would need to be defined, but would likely need to include foreswearing a parallel path to enrichment/reprocessing plus acceptance of the Additional Protocol for NNWS). The IAEA might either hold title to the material to be supplied or, more likely, act as facilitator, with back-up agreements between the IAEA and supplier countries to fulfil commitments made by the IAEA effectively on their behalf. In effect, the IAEA would be establishing a default mechanism, only to be activated in instances where a normal supply contract had broken down for reasons other than commercial reasons. The suggested pros and cons are therefore similar, with the added value of broad international assurances. Several questions can be raised with respect to the IAEA and its special status as an international organisation subject to the control of its Member-States. Any guarantee provided by the IAEA would in fact require approval by its Board of Governors.

15. Where an MNA would take the form of a joint facility, there are two ready-made precedents, the Anglo-Dutch-German company Urenco and the French EURODIF. The experience of Urenco, with its commercial/industrial management on the one hand and the governmental Joint Committee on the other hand, has shown that the multinational concept can be made to work successfully. Under this model, strong oversight of technology and staffing, as well as effective safeguards and proper international division of expertise can reduce the risk of proliferation and even make a unilateral breakout extremely difficult. EURODIF on the other hand has a successful multinational record as well, by enriching uranium only in one country, while providing enriched uranium to its co-financing international partners, hence restricting all proliferation risks, diversion, clandestine parallel programme, breakout and the spread of technology.

Reprocessing of nuclear spent fuel

16. Taking into account present capacities to reprocess spent fuel for light water reactors and those under construction, there will be sufficient reprocessing capacity globally for all expected demands in plutonium-recycled fuel during some two decades. Therefore, objectives of assurances of supply can be fulfilled to a large extent without new reprocessing facilities involving ownerships (Types II and III).

17. Currently all reprocessing plants are essentially State-owned. By the very nature of the nuclear business worldwide, any guarantee from a supplier would have the implicit or explicit

agreement of the corresponding government. As to *IAEA-brokered arrangements*, these could mean an IAEA participation in the supervision of an international consortium for reprocessing services.

18. *Converting a national facility* to international ownership and management would involve the creation of a new international entity that would operate as a new competitor in the reprocessing market. The pros reflect the advantages of bringing together international expertise, while the cons include non-proliferation disadvantages related to know-how dissemination and to the return of the separated plutonium. Other cons deal with the fact that, of the existing facilities, all except two Japanese facilities are in NWS or in non-NPT States. In many of those cases, appropriate safeguards will have to be introduced if they had not been applied before.

19. As noted above, the *construction of new joint facilities* will not be needed for a long time. Therefore, a prerequisite for the construction of new facilities is the demand for additional reprocessing and for recycled-plutonium fabrication. In the future such reprocessing and fabrication would be done on the same location.

Spent fuel disposal

20. At present there is no international market for spent fuel disposal services, as all undertakings are strictly national. The final disposal of spent fuel is thus a candidate for multilateral approaches. It offers major economic benefits and substantial non-proliferation benefits, although it presents legal, political and public acceptance challenges in many countries. The Agency should continue its efforts in that direction by working on all the underlying factors, and by assuming political leadership to encourage such undertakings.

21. The final disposal of spent fuel (and radioactive waste as well) in shared repositories must be looked at as only one element of a broader strategy of parallel options. National solutions will remain a first priority in many countries. This is the only approach for States with many nuclear power plants in operation or in past operation. For others with smaller civilian nuclear programmes, a dual-track approach is needed in which both national and international solutions are pursued. Small countries should keep options open (national, regional or international), be it only to maintain a minimum national technical competence necessary to act in an international context.

Spent fuel storage

22. Storage facilities for spent fuel are in operation and are being built in several countries. There is no international market for services in this area, except for the readiness of the Russian Federation to receive Russian-supplied fuel, and with a possible offer to do so for other spent fuel. The storage of spent fuel is also a candidate for multilateral approaches, primarily at the regional level. Storage of special nuclear materials in a few safe and secure facilities would enhance safeguards and physical protection. The IAEA should continue investigations in that field and encourage such undertakings. Various countries with state-of-the-art storage facilities in operation should step forward and accept spent fuel from others for interim storage.

Combined option: fuel-leasing/fuel take-back

23. In this model, the leasing State provides the fuel through an arrangement with its own nuclear fuel "vendors". At the time the government of the leasing State issues an export license to its fuel "vendor" corporation to send fresh fuel to a client reactor, that government would also announce its plan for the management of that fuel once discharged. Without a specific spent fuel management scheme by the leasing State, the lease deal will of course not take place. The leased fuel once removed from the reactor and cooled down, could either be returned to its country of origin which

owns title to it, or, through an IAEA-brokered deal could be sent to a third party State or to a multinational or a regional fuel cycle centre located elsewhere for storage and ultimate disposal.

24. The weak part in the arrangement outlined above is the willingness, indeed the political capability, of the leasing State to take-back the spent fuel it has provided under the lease contract. It could well be politically difficult for any State to accept spent fuel not coming from its own reactors (that is, reactors producing electricity for the direct benefit of its own citizens). Yet, to make any lease-take-back deal credible, an ironclad guarantee of spent fuel removal from the country where it was used must be provided, otherwise the entire arrangement is moot. In this respect, States with suitable disposal sites, and with grave concerns about proliferation risks, ought to be proactive in putting forward solutions. Of course, commitment of client States to forego enrichment and reprocessing would make such undertakings politically more tolerable.

25. As an alternative, the IAEA could broker the creation of multinational or regional spent fuel storage facilities, where spent fuel owned by leasing States and burned elsewhere could be sent. The IAEA could thus become an active participant in regional spent fuel storage facilities, or third party spent fuel disposal schemes, thereby making lease-take-back fuel supply arrangements more credible propositions.

Overarching issues

26. Apart from the cross-cutting factors related to the implementation of MNAs, such as the technical, legal and safeguards ones, there are a number of overarching issues, primarily of a broad political nature, which may have a bearing upon perceptions of the feasibility and desirability of MNAs. These issues may be decisive in any future endeavour to develop, assess and implement such approaches at the national and international level.

Relevant articles of the NPT

27. The NPT incorporates a political bargain with respect to peaceful uses and nuclear disarmament without which the Treaty would not have been adopted nor received the widespread adherence it obtained afterwards. The promise by all States parties to cooperate in the further development of nuclear energy and for the NWS to work towards disarmament provided the basis for NNWS to abstain from acquiring nuclear weapons.

28. Cooperation in the peaceful uses of nuclear energy, which had earlier provided the basis for the foundation of the IAEA, is embodied in Article IV, which stipulates that nothing shall be interpreted as affecting the "*inalienable right of all Parties to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II*" (that specify the non-proliferation objectives of the Treaty). Furthermore, that same article specifies that all Parties to the NPT shall undertake to "*facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy*", and moreover to "*cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes...*" Article IV was specifically crafted to preclude any attempt to reinterpret the NPT so as to inhibit a country's right to nuclear technologies - so long as the technology is used for peaceful purposes.

29. NNWS have expressed dissatisfaction about what they increasingly view as a growing imbalance in the NPT: that, through the imposition of restrictions on the supply of materials and equipment of the nuclear fuel cycle by the NWS and the advanced industrial NNWS, those States have backed away from their original guarantee to facilitate the fullest possible exchange referred

to in Article IV and to assist all NNWS in the development of the applications of nuclear energy. There are also concerns that additional constraints on Article IV might be imposed.

30. Article VI of the Treaty obliges NWS Parties "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Many NNWS deem the implementation of Article VI of the NPT by NWS as unsatisfactory, as are the non-entry into force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and the stalemate in the negotiations on a verifiable Fissile Material (Cut-off) Treaty (FM(C)T). Such concerns have fostered a conviction among many NNWS that the NPT bargain is being corroded.

Safeguards and export controls

31. Some States have argued that, if the objective of MNAs is merely to strengthen the nuclear non-proliferation regime then, rather than focusing on MNAs, it may be better to concentrate instead on the existing elements of the regime itself, for example, by seeking the universality of the Additional Protocol (AP) to IAEA safeguards agreements and by the universalisation of safeguards agreements and multilateral export controls.

32. The risks involved in the spread of sensitive nuclear technologies should primarily be addressed by an efficient and cost-effective safeguards system. The IAEA and regional safeguards systems have done an outstanding job in these matters. Safeguards, rationally and well applied, have been the most efficient way to detect and deter further proliferation and to provide States Parties with an opportunity to assure others that they are in conformity with their safeguards commitments. Of course, advances in technologies require safeguards to be strengthened and updated, while protecting commercial, technological and industrial secrets. The adoption of the Additional Protocol, and its judicious implementation based on State-level analysis, are essential steps against further nuclear proliferation. The Additional Protocol has proven to provide additional, necessary and effective verification tools, while protecting legitimate national interests in security and confidentiality. Sustained application of the Additional Protocol in a State can provide credible assurance of the absence of undeclared materials and activities in that State. Together with a comprehensive safeguards agreement, the Additional Protocol should become the de facto safeguards standard.

33. The above notwithstanding, the IAEA should endeavour to further strengthen the implementation of safeguards. For example, it should revisit three facets of its verification system:

a. The technical annexes of the Additional Protocol, which should be regularly updated to reflect the continuing development of nuclear techniques and technologies.

b. The implementation of the AP, which requires adequate resources and a firm commitment to apply it decisively. It should be recalled that the Model Additional Protocol commits the IAEA not to apply the AP in a mechanistic or systematic way. Therefore the IAEA should allocate its resources on problematic areas rather than on States using the largest amounts of nuclear material.

c. The enforcement mechanisms in case of fundamental breach of, or in case of non-compliance with, the safeguards agreement. Are these mechanisms progressive enough to act as an effective deterrent? Further consideration should be given by the IAEA to appropriate measures to handle various degrees of violations.

34. Export guidelines and their implementation are an important line of defence for preventing proliferation. Recent events have shown that criminal networks can find ways around existing

controls to supply clandestine activities. Yet, one should remember that all States party to the NPT are obliged, pursuant to Article III.2 thereof, to implement export controls. This obligation was reinforced by United Nations Security Council Resolution 1540 (2004) that requires all States to enact and implement export controls to prevent the spread of weapons of mass destruction and related materials to non-State actors. The participation in the development and implementation of export controls should be broadened, and multilaterally-agreed export controls should be developed in a transparent manner, engaging all States.

35. In fact, the primary technical barriers against proliferation remain the effective and universal implementation of IAEA safeguards under comprehensive safeguards agreements and additional protocols, and effective export controls. Both must be as strong as possible on their own merits. MNAs will be complementary mechanisms for strengthening the existing non-proliferation regime.

Voluntary participation in MNAs versus a binding norm

36. The present legal framework does not oblige countries to participate in MNAs, as the political environment makes it unlikely that such a norm can be established any time soon. Establishing MNAs resting on ***voluntary*** participation is thus the more promising way to proceed. In a voluntary arrangement covering assurances of supply, recipient countries would, at least for the duration of the respective supply contract, renounce the construction and operation of sensitive fuel cycle facilities and accept safeguards of the highest current standards including comprehensive safeguards and the Additional Protocol. Where the demarcation line between permitted R&D activities and renounced development and construction activities has to be drawn is a matter for further consideration. In voluntary MNAs involving facilities, the participating countries would presumably commit to carry out the related activities solely under the common MNA framework.

37. In reality, countries will enter into such multilateral arrangements according to the economic and political incentives and disincentives offered by these arrangements. A political environment of mutual trust and consensus among the partners - based on full compliance with the agreed nuclear non-proliferation obligations of the partners - will be necessary to the successful negotiation, creation and operation of an MNA.

38. Beyond this, a new ***binding*** international norm stipulating that sensitive fuel cycle activities are to be conducted exclusively in the context of MNAs and no longer as a national undertaking would amount to a change in the scope of Article IV of the NPT. The wording and negotiation history of this article emphasise the right of each party in good standing to choose its national fuel cycle on the basis of its sovereign consideration. This right is not independent of the faithful abiding by the undertakings under Articles I and II. But if this condition is met, no legal barrier stands in the way of each State party to pursue all fuel cycle activities on a national basis. Waiving this right would thus change the "bargain" of the NPT.

39. Such a fundamental change is not impossible if the parties were to agree on it in a broader negotiating frame. For NNWS, such a new bargain can probably only be realised through universal principles applying to all States and after additional steps by the NWS regarding nuclear disarmament. In addition, a verifiable FM(C)T might also be one of the preconditions for binding multilateral obligations; such a treaty would terminate the right of any participating nuclear weapon States and non-NPT parties to run reprocessing and enrichment facilities for nuclear explosive purposes and it would bring them to the same level - with regard to such activities - as non-nuclear weapon States. The new restrictions would apply to all States and facilities related to the technologies involved, without exception. At that time, multilateral arrangements could become a universal, binding principle. The question may also be raised as to what might be the conditions required by NWS and non-NPT States to commit to binding MNAs involving them.

Nuclear-weapon States and non-NPT States

40. Weapon-usable material (stocks and flows) and sensitive facilities that are capable of producing such material are located predominantly in the NWS and non-NPT States. The concerns raised previously for MNAs in NNWS do not all apply when an MNA would involve NWS or non-NPT States. Yet, one of the questions here relates to the possibility that the nuclear material produced in an MNA could contribute to such a State's nuclear non-peaceful programme. This shows again the relevance of a FM(C)T.

41. The feasibility of bringing NWS and non-NPT States into MNAs should indeed be considered at an early stage. As long as MNAs remain voluntary, nothing would preclude such States from participating in an MNA. In fact, France (in connection with the EURODIF arrangement) and the United Kingdom (in connection with Urenco) are examples of such participation. In transforming existing civilian facilities into MNAs subject to safeguards and security requirements, such States would demonstrate their support for non-proliferation and for peaceful international nuclear collaboration.

Enforcement

42. Eventually, the success of all efforts to improve the nuclear non-proliferation regime depends upon the effectiveness of compliance and enforcement mechanisms. Enforcement measures in case of non-compliance can be partially improved by MNAs' legal provisions, which will carefully specify a definition of what constitutes a violation, by whom such violations will be ruled on, and enforcement measures that could be directly applied by the partners in addition to broader political tools.

43. Nevertheless, enhanced safeguards, MNAs, or new undertakings by States will not serve their full purpose if the international community does not respond with determination to serious cases of non-compliance, be it diversion, clandestine activities or breakout. Responses are needed at four levels, depending upon the specific case: the MNA partners of the non-compliant State; the IAEA; the States Parties to the NPT; and the UN Security Council. Where these do not currently exist, appropriate procedures and measures must be available and must be made use of at all four levels to cope with breaches and non-compliance instances, in order to unequivocally make clear that States violating treaties and arrangements should not be permitted to do so unimpeded.

Multilateral nuclear approaches: the future

44. Past initiatives for multilateral nuclear cooperation did not result in any tangible results. Proliferation concerns were perceived as not serious enough. Economic incentives were seldom strong enough. Concerns about assurances of supply were paramount. National pride also played a role, alongside expectations about the technological and economic spin-offs to be derived from nuclear activities. Many of those considerations may still be pertinent. However, the result of balancing those considerations today, in the face of a latent multiplication of nuclear facilities over the next decades and the possible increase in proliferation dangers may well produce a political environment more conducive to MNAs in the 21st century.

45. The potential benefits of MNAs for the non-proliferation regime are both symbolic and practical. As a confidence-building measure, multilateral approaches can provide enhanced assurance to the partners and to the international community that the most sensitive parts of the civilian nuclear fuel cycle are less vulnerable to misuse for weapon purposes. Joint facilities with multinational staff put all MNA participants under a greater degree of scrutiny from peers and partners and may also constitute an obstacle against a breakout by the host partner. They also

reduce the number of sites where sensitive facilities are operated, thereby curbing proliferation risks, and diminishing the number of locations subject to potential thefts of sensitive material. Moreover, these approaches can even help in creating a better acceptance for the continued use of nuclear power and for nuclear applications, and enhance the prospects for the safe and environmentally sound storage and disposal of spent nuclear fuel and radioactive waste.

46. As far as assurances of supply are concerned, multilateral approaches could also provide the benefits of cost-effectiveness and economies of scale for whole regions, for smaller countries or for those with limited resources. Similar benefits have been derived in the context of other technology sectors, such as aviation and aerospace. However, the case to be made in favour of MNAs is not entirely straightforward. States with differing levels of technology, different degrees of institutionalisation, economic development and resources and competing political considerations may not all reach the same conclusions as to the benefits, convenience and desirability of MNAs. Some might argue that multilateral approaches point to the loss or limitation of State sovereignty and independent ownership and control of a key technology sector, leaving unfairly the commercial benefits of these technologies to just a few countries. Others might argue that multilateral approaches could lead to further dissemination of, or loss of control over, sensitive nuclear technologies, and result in higher proliferation risks.

47. In summary, the Expert Group on Multilateral Approaches for the Nuclear Fuel Cycle has reviewed the various aspects of the fuel cycle, identified a number of options for MNAs deserving further consideration, and noted a number of pros and cons for each of the options. It is hoped that the report of the Expert Group will serve as a building block, or as a milestone. It is not intended to mark the end of the road. MNAs offer a potentially useful contribution to meeting prevailing concerns about assurances of supply and non-proliferation.

48. The Group recommends that steps be taken to strengthen overall controls on the nuclear fuel cycle and the transfer of technology, including safeguards and export controls: the former by promoting universal adherence to Additional Protocols, the latter through a more stringent implementation of guidelines and a universal participation in their development.

49. In order to maintain momentum, the Group recommends that attention be given - by the IAEA Member States, by the IAEA itself, by the nuclear industry and by other nuclear organisations - to multilateral nuclear approaches in general and to the **five approaches** suggested below.

Five suggested approaches

The objective of increasing non-proliferation assurances associated with the civilian nuclear fuel cycle, while preserving assurances of supply and services around the world could be achieved through a set of gradually introduced multilateral nuclear approaches (MNA):

1. Reinforcing **existing commercial market mechanisms** on a case-by-case basis through long-term contracts and transparent suppliers' arrangements with government backing. Examples would be: fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks.

2. Developing and implementing **international supply guarantees** with IAEA participation. Different models should be investigated, notably with the **IAEA as guarantor** of service supplies, e.g. as administrator of a fuel bank.

3. Promoting voluntary conversion of **existing facilities to MNAs**, and pursuing them as **confidence-building measures**, with the participation of NPT non-nuclear- weapon States and nuclear-weapon States, and non-NPT States.

4. Creating, through voluntary agreements and contracts, **multinational, and in particular regional, MNAs for new facilities** based on joint ownership, drawing rights or co-management for front-end and back-end nuclear facilities, such as uranium enrichment; fuel reprocessing; disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.

5. The scenario of a further expansion of nuclear energy around the world might call for the development of a **nuclear fuel cycle with stronger multilateral arrangements** – by region or by continent - **and for broader cooperation**, involving the IAEA and the international community.

Chapter 1 - Foreword

Background

1. In his statement to the IAEA General Conference in September 2003, the Director General observed that international cooperation in the context of the design and operation of the nuclear fuel cycle was an important issue that had been discussed over the years, but which, in his view, now merited serious consideration as part of the global effort to cope with increasing nuclear non-proliferation and security challenges. He stated that such consideration should include an evaluation of the merits of limiting the use of weapon-usable material (high enriched uranium and plutonium) in civilian nuclear programmes, by permitting it only under multilateral control, and that any exploration of this kind had to be accompanied by appropriate rules of transparency, control and, above all, assurance of supply of nuclear fuel cycle services. He emphasized that strengthened control of weapons usable material was key to efforts to strengthen nuclear non-proliferation and to enhance international security. These proposals were refined and reiterated in his October 2003 article published in *The Economist.*[1]

2. The Director General also referred to the need to consider the merits of multinational approaches to the management and disposal of spent nuclear fuel and radioactive waste. As he pointed out, not all countries have the appropriate conditions for geologic disposal - and, for many countries with small nuclear programmes for electricity generation or for research, the financial and human resource investments required for research, construction and operation of a geologic disposal facility were not available. Considerable economic, safety, security and non-proliferation advantages may therefore accrue from international cooperation on the construction and operation of international nuclear spent fuel and waste repositories. In his statement of September 2003, the Director General also indicated that the merits and feasibility of these and other approaches to the design and management of the nuclear fuel cycle should be given in-depth consideration.

3. In March 2004, in his statement to the IAEA Board of Governors, the Director General referred to the wide dissemination of the most proliferation-sensitive parts of the nuclear fuel cycle – the production of new fuel, the processing of weapon-usable material and the disposal of spent fuel – as the possible "'Achilles' heel' of the nuclear non-proliferation regime", and to the importance of tightening control over such operations. He indicated that this could be done by bringing such parts of the nuclear fuel cycle under some form of multilateral control, with appropriate checks and balances to preserve commercial competitiveness, to control the proliferation of sensitive information and to ensure the supply of fuel cycle services for peaceful applications. The Director General informed the Board that he would appoint an independent group of experts to examine the feasibility of moving forward with such measures.

4. In June 2004, the Director General informed the Board of Governors that he had appointed an international expert group, chaired by Bruno Pellaud, former IAEA Deputy Director General for Safeguards, to consider options for possible multilateral approaches to the front and back ends of the nuclear fuel cycle (multilateral nuclear approaches, MNA).

5. The IAEA serves as the global focal point for nuclear cooperation and is tasked with a dual objective: "to accelerate and enlarge the contribution of atomic energy to peace, health and

[1] ELBARADEI, M., Towards a safer world, The Economist, 16 October (2003).

prosperity throughout the world" and to "ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."[2]

Mandate

6. The mandate of the Expert Group was three-fold:

- To identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;
- To provide an overview of the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and
- To provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

7. The Director General, in his invitation to the experts, stated that he expected that this work may result in practical proposals which, if implemented, could provide enhanced assurance to the international community that sensitive portions of the nuclear fuel cycle are less vulnerable to misuse for proliferation purposes and thereby facilitate the continued uses of nuclear energy for peaceful purposes.

8. Speaking on the occasion of the first meeting of the Expert Group, the Director General, in elaborating on the Group's mandate, recommended that it address the issue in all of its various facets, and in particular to assess the potential for a positive impact on international security. He requested the Group to take into account the perceptions and expectations of all interested stakeholders and stressed that, to be successful, new approaches must go beyond the outright denial of technology. The Director General noted the importance of examining multilateral options with respect to both the front end and the back end of the civilian fuel cycle, noting that any solution must be inclusive and without reference to the status of particular countries under the NPT. He asked the Group not to confine itself to finding "one-size-fits-all approaches" and cautioned that what works in one region may not be the most ideal approach in another. He also agreed that the concept of multilateral nuclear approaches could be placed in the broader context of the nuclear non-proliferation regime as a whole, including the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), a verifiable Fissile Material (Cut-off) Treaty (FM(C)T) and other relevant agreements.

9. The Expert Group held a series of four one-week meetings over the period August 2004 to February 2005, at the IAEA headquarters in Vienna. The Group consisted of individuals, participating in their personal capacity, selected by the Director General to represent a broad spectrum of experience and nationalities, all of whom had been associated with the nuclear field in one capacity or another for many years. A list of the Expert Group members is set out in Annex 2 to this report. The Expert Group was assisted in its efforts by Messrs. Lawrence Scheinman and Wilhelm Gmelin as advisors, as well as a number of current and former staff members of the IAEA and external experts, who are also identified in Annex 2.

10. Although the Expert Group agreed to forward its report to the Director General, it is important to note that the report does not necessarily reflect agreement by all of the experts on the desirability or feasibility of MNAs, or on all of the options. Nor does it reflect a consensus assessment of their respective value. It is intended only to present possible options for MNAs and to reflect on the range of factors that could influence the consideration of those options.

[2] IAEA Statute, Article II, IAEA, Vienna (1989).

Preliminary Considerations

11. At the outset of its deliberations, the members of the Expert Group expressed the collective expectation that nuclear energy will continue to play a significant role in supplying the world with energy, and that given the dual nature of nuclear technology, reliable and effective existing and new multilateral arrangements are necessary to prevent the further proliferation of nuclear weapons. The Group felt therefore that in fulfilling its mandate, its purpose was to assess MNAs in the framework of a two-pronged objective: strengthening the international nuclear non-proliferation regime while securing the peaceful uses of nuclear energy.

12. Beyond long-standing issues such as universality, the nuclear non-proliferation debate has been driven by new challenges to the existing non-proliferation regime, inter alia: the discovery of undeclared nuclear material and activities in certain NPT non-nuclear-weapon States (NNWS); the existence of clandestine supply networks for the acquisition of nuclear technology; and the risk of "breakout" from the NPT by States within the regime. Several proposals have been put forward with a view to ensuring that the nuclear non-proliferation regime maintains its authority, effectiveness and credibility in the face of these very real challenges. One of these proposals calls for the denial of sensitive technology to NNWS not already possessing such facilities. This has been seen by many as inconsistent with the letter and spirit of Article IV of the NPT. There is a consistent opposition by many NNWS to accept additional restrictions on their development of peaceful nuclear technology without equivalent progress on disarmament. Other proposals have focused on the strengthening and effective application of the IAEA's safeguards system. Another proposal is for multilateral approaches to the operation of those parts of the nuclear fuel cycle considered to be of the greatest sensitivity from the point of view of proliferation risk. It is this latter proposal that the Expert Group was asked to consider.

13. First, a word about terminology. In the view of the Expert Group, a distinction should be made between the words "*multilateral*" (the broadest and most flexible term, referring simply to the participation of more than two actors), "*multinational*" (implying several actors from different States), "*regional*" (several actors from neighbouring States) and "*international*" (actors from different States and/or international organisations, such as the IAEA). The Group has been asked to address the broadest possible options, and has thus explored all multilateral options, whether multinational, regional or international.

14. In addition, it was necessary to define what the Expert Group considered to be those parts of the nuclear fuel cycle of the greatest sensitivity from the point of view of proliferation risk. As can be seen from the structure of the report, the Group decided to address *uranium enrichment, reprocessing* and *spent fuel disposal and storage*.

15. In fulfillment of its mandate, the Expert Group decided to address three inter-related elements:

a. **Current and historical experiences** with MNAs: *What has already been tried in this regard? How successfully?* Chapters 2 and 3 provide the background on the mandate of the Expert Group and on the political and historical contexts of the issue of MNAs. The Group benefited from accumulated experience with existing successful multilateral solutions, particularly in Europe. The Group took advantage of work previously carried out under the auspices of the IAEA, as well as in other fora. In addition, there is a wealth of practical experience with multilateral approaches not only in the nuclear field, but in other fields of technology, such as aviation and space, to name only two.

b. **Factors, options, and incentives and disincentives**: Chapters 4 and 5 address, collectively and individually: policy, legal, security, economic and technological factors relevant to MNAs in connection with the four sectors of the nuclear fuel cycle identified above (paragraph 14). Chapter 4 discusses cross-cutting factors. Chapter 5 reflects the Experts Group's analysis of

the factors specific to, and possible options associated with, each of those sectors and identifies the corresponding benefits and disadvantages (pros and cons) of the various options.

c. **Over-arching considerations and recommendations**: Chapter 6 addresses overarching issues, primarily of a broad political nature, that may affect perceptions as to the feasibility and desirability of MNAs. Chapter 7 reflects on the conclusions of the Expert Group and offers recommendations on possible ways forward with MNAs.

16. Drawing on historical experiences with MNAs, borrowing materials and concepts from past and current examples, and aware of the current political context, the Group hopes to have shed some light on multilateral cooperation and have identified a number of possible options and approaches that could serve the nuclear community in the years to come in the search for a strong nuclear fuel cycle.

Chapter 2 - Current Political Context

17. The global nuclear non-proliferation regime has been successful in limiting, albeit not entirely preventing, the further spread of nuclear weapons. The vast majority of States have legally pledged to forego the manufacture and acquisition of nuclear weapons and have abided by that commitment. Nevertheless, the past few years have been a tumultuous and difficult period, during which new challenges to the international non-proliferation system have surfaced.

18. The decades long nuclear non-proliferation effort is under threat: from regional arms races; from fundamental breaches of, or non-compliance with, safeguards agreements, without fully corrective action; from the incomplete manner in which export controls required by the NPT have been applied; from burgeoning and alarmingly well-organised nuclear supply networks; and from the increasing risk of acquisition of nuclear or other radioactive materials by terrorist and other non-State entities.

19. An emerging new concern is that of possible "breakout" from the NPT, as exemplified by the actions of the DPRK. The postulated scenario is that an NNWS acquires sensitive elements of a nuclear fuel cycle – uranium enrichment and/or plutonium separation – ostensibly for peaceful purposes as provided for under the NPT, but then withdraws from the Treaty giving the required three months notice and subsequently is free to utilize its nuclear capability for developing nuclear weapons. The closest instance of such an unwelcome development is the case of the Democratic People's Republic of Korea (DPRK) – which was determined to be in "further non-compliance" with its NPT safeguards agreement by the IAEA Board of Governors and then announced its withdrawal from the NPT. To date, this announcement has not incurred any action by the UN Security Council. Recently the DPRK has again claimed that it possesses nuclear weapons. While most of the DPRK's nuclear material and infrastructure was acquired prior to its accession to the NPT and entry into force of its NPT safeguards agreement, the international community finds the withdrawal unacceptable, and in breach of good faith in treaty law, that the DPRK has announced its departure from the NPT, remains in non-compliance with its NPT safeguards agreement, may have been involved in the clandestine nuclear supply networks and may be developing nuclear weapons. Reversal of this "DPRK nuclear crisis" and the prevention of any similar scenario remains a high priority for the international community.

20. Furthermore, many NNWS have long voiced concerns that the five NPT nuclear-weapon States (NWS) are not making sufficient progress in fulfilling their nuclear disarmament commitments under the NPT. While some progress has been made, shortfalls continue to draw sharp criticism from many NNWS, which cite them as a major disincentive to support further non-proliferation initiatives that impact upon the NNWS. The same applies to the continuing delay in the initiation of negotiations on a verifiable Fissile Material (Cut-off) Treaty (FM(C)T), and in the entry into force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) – two measures that have been on the global nuclear non-proliferation and disarmament agenda for decades.

21. As stated by the IAEA Director General, in his speech at the Carnegie Conference in June 2004: "any new adjustment to the [nuclear non-proliferation and disarmament] regime must include" the non-NPT States.

22. Despite these challenges, there have been positive developments. Membership in the NPT now stands at 189 countries (including the DPRK). Supplier countries now seek to exercise greater vigilance in their export controls. Meanwhile, in response to the IAEA's uncovering of Iraq's undeclared nuclear-weapon programme in the early 1990's, the international community moved decisively to strengthen the IAEA's safeguards system, and to adopt the Model Additional Protocol (INFCIRC/540 (Corr.)) as a standard feature of the IAEA safeguards system. The Model Additional Protocol provides the Agency more information on nuclear activities and future plans, and with

more verification tools including, inter alia, extensive physical access to all sites and places where nuclear material is located as well to nuclear activities not involving nuclear material in order to provide credible assurance of the absence of undeclared nuclear material and activities. The IAEA uses more advanced equipment for the verification of nuclear material, including unattended data transmission and is more sophisticated, alert and responsive in assessing State's nuclear activities. These new arrangements are already having a positive impact on the level of confidence in IAEA safeguards, and have led to proposals to make the Additional Protocol a norm under the NPT. Efforts to create additional treaty-based nuclear-weapon-free zones, incorporating IAEA safeguards for verification, are another positive signal.

23. International collaboration between the Russian Federation and the United States in the "*Megatons to Megawatts*" programme[3] has resulted in large quantities of high enriched uranium (HEU) released from dismantled Russian warheads being down-blended into low-enriched uranium (LEU) for civilian use. In addition, a significant portion of US-supplied HEU research reactor fuel has now been recovered under US take-back programmes. Similar actions are now also being taken with respect to Russian-supplied HEU fuel. United Nations Security Council resolution 1540 (2004) was adopted to prevent access to materials for nuclear and other weapons of mass destruction by terrorist groups and non-State actors, and it has made it mandatory for all States to implement appropriate national control system to secure such materials.

24. A different significant factor is that the civilian nuclear industry appears to be poised for worldwide expansion. Rapidly growing global demand for electricity, the uncertainty of supply and price of natural gas, soaring prices for oil, concerns about air pollution and the immense challenge of lowering greenhouse gas emissions, are all driving a fresh look at nuclear power. As the technical and organisational foundations of nuclear safety improve, there is increasing confidence in the safety of nuclear power plants. In light of existing, new and reawakened interest in many regions of the world, the prospect of new nuclear power stations on a large scale is real. A greater number of States will consider developing their own fuel cycle facilities and nuclear know-how, and will seek assurances of supply in materials, services and technologies.

25. States have sought such capabilities for a variety of reasons: to carry out entirely legitimate, peaceful programmes; to remove doubts about the reliability of fuel supply from foreign sources; to conserve nuclear fuel resources through reprocessing; to achieve the prestige of possessing advanced, sophisticated fuel cycle facilities; to benefit from industrial, technological and scientific spin-offs; to sell enrichment or reprocessing services on the international market; and because the State considers it to be economically justifiable. A few States have also sought such technologies – research reactors and fuel fabrication – for the purpose of developing nuclear weapons or securing the option to do so.

26. Historically, the States that wanted nuclear weapons have gone straight for them[4], creating dedicated weapons programmes. Nonetheless, without adequate controls, the civil nuclear fuel cycle has been used to support to a weapons programme in a few instances. Despite strengthened IAEA safeguards, clearly it is not desirable from a non-proliferation point of view that every State with nuclear research and/or nuclear energy programmes should necessarily establish

[3] The *Megatons to Megawatts* programme is a commercially financed government-industry partnership in which bomb-grade uranium from dismantled Russian nuclear warheads is being diluted and recycled into fuel used mainly by American power plants. Begun in 1994, the programme is being implemented by USEC, as executive agent for the U.S. government, and TENEX, acting for the Russian government. By its completion in 2013, the programme is expected to have recycled 500 tonnes of nuclear weapons material (the equivalent of 20,000 warheads) into fuel equivalent to 14% (5.5 million SWU) of the current global enrichment demand.

[4] NEFF, T.L. "The Nuclear Fuel Cycle and the Bush Non-Proliferation Initiative", World Nuclear Fuel Cycle 2004 (Proc. Int. Conf. Madrid 2004).

its own enrichment and reprocessing facilities (even if such activities would be within the boundaries of Article IV of the NPT)[5].

27. In the 1970s, the search for alternative approaches to complete national fuel cycles, fuelled by growing concerns regarding prospective "plutonium economies" and the 1974 nuclear explosion by India, led in turn to a number of international initiatives, which are the central elements of the historical perspective provided in the following chapter.

[5] Recent proposals highlighting the need to address the potential proliferation risk of the civilian nuclear fuel cycle include, inter alia: 11 February 2004 speech at the National Defense University by US President George W. Bush; written ministerial statement by UK Foreign Secretary Jack Straw, 25 February 2004; the G-8 statement at their June 2004 summit; further proposals by the IAEA Director General Mohamed ElBaradei; the report of the UN Secretary General's High Level Panel on Threats, Challenges and Change, December 2004.

Chapter 3 - Historical Perspective

28. At the very outset of the nuclear age, it was recognised that the atom had both peaceful and military applications. The internationalisation of nuclear technology has its origins in the 1946 Baruch Plan, in which the United States proposed that States should transfer ownership and control over civil nuclear activities and materials to an international atomic development agency. Nearly a decade later, in 1953, US President Eisenhower unveiled his Atoms for Peace plan. This, in turn, laid the ground not only for the establishment of the IAEA, but also for widespread dissemination of civilian nuclear knowledge and technology. All of this heightened concerns that, with unlimited access to the technologies of nuclear fission and the fuel cycle, someone, somewhere would light a fuse igniting further nuclear weapons proliferation.

29. The NPT was intended to halt such proliferation by limiting the NWS to those States that had manufactured and detonated a nuclear explosive device prior to 1 January 1967, and committed all parties, under Article VI of the Treaty, "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament") and, in respect of the NNWS, by requiring that their nuclear activities be for peaceful purposes only and subject to the safeguards system of the IAEA. As has been noted, the NPT has been remarkably successful in limiting the spread of nuclear weapons, in spite of challenges to the regime. Some of these challenges are not new, having loomed particularly large in the 1970s, and led to considerable diplomatic activity and related initiatives – including proposals for multilateral arrangements.

30. One of the most significant events of that time was the "peaceful nuclear explosion" carried out by India in May 1974. Another was the oil crisis of the mid-to-late 1970s, which gave rise both to plans for, and expectations of, an exponential rise in the number of nuclear facilities in order to meet global energy demands. Essentially, the world was facing the prospect of large scale equipment and material transfers, all bearing on the most sensitive aspects of the nuclear fuel cycle, combined with the dissemination of knowledge of nuclear fission and its various uses, as well as associated training. Particular anxiety was expressed at the time about the prospective escalation in the number of reprocessing facilities (the "plutonium economy") and the consequent increased risk of horizontal proliferation and sub-national theft.

31. The resulting concern about managing this process while ensuring respect for non-proliferation norms, led to a number of proposals for regional, multilateral and international arrangements. The proposals were intended, on the one hand, to reinforce the NPT objective of discouraging horizontal proliferation and, on the other, not to undermine the right of all States to exploit nuclear energy for peaceful purposes. The IAEA General Conference briefly looked at the issue in 1974, with specific reference to the possibility of establishing internationally approved facilities to handle all spent fuel produced in power reactors. The Final Declaration of the 1975 NPT Review Conference also included a finding that "*regional or multinational nuclear fuel cycle centres may be*

an advantageous way to satisfy, safely and economically, the needs of many States, while, at the same time facilitating protection and the application of safeguards."

32. Among the more visible efforts to promote MNAs in the 1970s and 1980s were: the IAEA study on Regional Nuclear Fuel Cycle Centres (1975-77); the International Nuclear Fuel Cycle Evaluation programme (1977-80); the Expert Group on International Plutonium Storage (1978-82); and the IAEA Committee on Assurances of Supply (1980–1987). In a general sense, these studies concluded that most of the proposed arrangements were technically feasible and that, based on the projections of energy demand, economies of scale rendered them economically attractive.

a. The Regional Nuclear Fuel Cycle Centres (RFCC) study (1975-77), the first of the 1970s initiatives, looked into the possibility of pooling States' resources into regional fuel cycle centres[6]. The focus, as was the case for most of the initiatives at that time, was on the back end of the cycle, specifically reprocessing and plutonium containment. The conclusion of the RFCC study, in brief, was that the proposal was technically valid, but that problems could arise concerning technology transfer, physical protection and the possible risk of host country obstruction.
b. The International Nuclear Fuel Cycle Evaluation (INFCE) study (1977-80), which was prompted by concerns about the widespread use of plutonium, also looked into the possibility of regional fuel cycle facilities, as well as other models for multilateral plutonium storage[7]. Again, the technical conclusions were generally positive, but were overtaken by other aspects of the INCFE findings, which tended to focus on whether a technological fix might exist for reducing proliferation risks. At the end of its three years, the work of INFCE arrived at the general conclusion that no single fuel cycle approach was inherently superior to another from the standpoint of non-proliferation and that, while options to increase resistance might be worth pursuing, technical measures alone would not compensate for weaknesses of the international nuclear non-proliferation regime.
c. The Expert Group on International Plutonium Storage (IPS) (1978-82) explored the mandate of the IAEA under Article XII.A.5 of its Statute, which contemplates IAEA-supervised management, storage and release of plutonium[8]. A separate Expert Group on Spent Fuel Storage was also convened. No consensus on either of these initiatives proved possible.
d. The studies undertaken by the IAEA Committee on Assurances of Supply (CAS)[9] (1980-87), which also discussed the concept of multilateral approaches as a central part of its agenda, suffered a similar fate.
e. Another later effort to achieve concrete progress on multilateral approaches - the United Nations Conference for the Promotion of International Cooperation in the Peaceful Uses of Nuclear Energy (UNCPICPUNE) of 1987 – was no more successful. Essentially, UNCPICPUNE, which was seven years in gestation, could not generate specific conclusions, owing to a lack of political consensus on the matter.

33. All of these initiatives failed for a variety of political, technical and economic reasons, but mainly because parties could not agree on the non-proliferation commitments and conditions that would entitle States to participate in the multilateral activities. Moreover, differences of views prevailed between those countries and/or regions that did not plan

[6] REGIONAL FUEL CYCLE CENTRES, 1977 Report of the IAEA Study Project (vols. I & II), IAEA, Vienna (1977).
[7] INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION "INFCE Summary Volume", (INFCE/PC/2/9), IAEA, Vienna (1980).
[8] Expert Group on International Plutonium Storage – Report to the Director General, IAEA-IPS/EG/140(Rev.2), IAEA, Vienna (1982).
[9] Documents and Papers Issued for CAS (CAS/INF/4), IAEA, 1985.

to reprocess or recycle plutonium and those that favoured it (the latter group being concerned, in particular, about the availability of fuel supplies and the possibility of the interruption of supplies by suppliers). In addition, much of the momentum collapsed with the slowdown in new civil nuclear programmes in significant parts of the developed world, thereby *de facto* limiting the spread of reprocessing facilities and temporarily laying to rest fears of a global plutonium economy. As a consequence, efforts to establish multilateral mechanisms had wilted by the end of the 1980s.

34. There things remained until the 1997 International Symposium on the Nuclear Fuel Cycle and Reactors, which at the time received little public profile, but which, in retrospect, can be credited with expanding the focus on multilateral approaches from the back end of the cycle (reprocessing) to include the front end (enrichment). One of the most significant conclusions of this symposium was that the previous initiatives had failed because of the difference in priorities motivating governments as opposed to the nuclear industry: for the former, the priorities were political legitimacy and public support; for the latter, technical feasibility and commercial viability. As reflected in the results of the symposium, the great challenge ahead would be to reconcile these different priorities.

35. Then, through a series of IAEA sponsored meetings in 2001 and 2002, the focus on multilateralisation of the fuel cycle was broadened beyond reprocessing and enrichment to include repositories for spent fuel and nuclear waste. Once again, the deliberations suggested that, while political and institutional issues were the major obstacles to the establishment of such facilities, technical and economic considerations would favour them. The meetings led to the development of an Agency Technical Document (TECDOC) on developing multinational radioactive waste repositories[10].

36. Today these concepts have gained renewed salience and prompted the Director General's September 2003 proposal to reconsider such concepts. The nuclear non-proliferation regime faces some old challenges (national versus multinational operation of sensitive facilities; secure fuel supply; concerns over perceived limitations of the NPT); and, as discussed previously, it is confronted by dramatic and immediate new challenges. Some trends suggest that there might be a greater likelihood of success in the development of MNAs. Today, both States and international organisations have more experience with safeguards; with the commercial operation of sensitive facilities and nuclear fuel markets; with information monitoring and intelligence assessment; and with the identification of pathways to nuclear weapons. Given the challenges to the regime, they may also have greater motivation to look for solutions. The overall challenge to the Group, as noted in Para 15 above, is to use previous experience and current insights to define promising options for MNAs that would advance both the non-proliferation regime and the effective functioning of peaceful nuclear fuel cycles.

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation, IAEA-TECDOC-1413, IAEA, Vienna 2004

Chapter 4 - Cross-cutting factors

37. Consideration of multilateral approaches to the nuclear fuel cycle tends to involve certain common factors, whether dealing with enrichment, reprocessing storage or disposal. As foreseen in the Director General's mandate to the Expert Group, these cross-cutting factors extend across the spectrum of nuclear technology, economics, assurances of supply, legal and institutional arrangements, and non-proliferation and security issues. These cross-cutting factors are discussed in this chapter.

4.1 - Advances in nuclear technologies

38. This section deals with a major proliferation factor and its impact on safeguards and verification, namely the degree to which new technologies and other scientific developments interact with each other to lower the threshold of accessibility for sensitive nuclear technologies while permitting more effective and efficient verification by the IAEA.

39. Since the 1970s, nuclear technology has undergone significant developments, such as:

40. Information technology (IT): IT has changed dramatically since the 1970s, due to the introduction of faster, smaller, more versatile, low cost and more reliable computers and operating systems. For example, complex multi-group codes and hydrodynamic calculations that once took hours on the then-fastest super computers (Cray-1) may now be performed on a € 2000 personal computer in the same time or faster, especially when connected with other personal computers in a network.

41. However, the most significant IT development has been the appearance, spread and the usage of the Internet, where, apart from making information widely available and thereby fostering knowledge, a wealth of sensitive nuclear technology designs, methods and techniques can be retrieved worldwide with little difficulty (for example, early generations of production centrifuges for uranium enrichment, reprocessing flow sheets, including detailed descriptions of the radiochemistry involved).

42. Sensor technology, process engineering and miniaturisation: All kinds of sensors for physical parameters – such as optical (satellites), radiation, pressure and motion sensors – are now available at low cost. These processes have been both optimised and miniaturised and are now radiation-resistant and economical. Developments in this area facilitate the implementation of safeguards though the use of remote monitoring, installed systems and hand-held sensors.

43. Material technology: Examples are the use of non-metallic components in enrichment and reprocessing processes. Dual use materials have become ubiquitous in the nuclear realm.

44. Chemistry. Basic research has resulted in the development of new techniques for reprocessing, for example with pyrochemical processes with which large separation factors can be routinely achieved in small geometries. Analytical methods have been considerably improved, so that concentrations of smaller than one millionth of one millionth[11] are routinely determined. Such developments are particularly important for Agency verification.

[11] Chemists claim that such low concentrations are equivalent to the concentration of a lump of sugar dissolved in a volume of water as large as the Baltic Sea.

45. Finally, the **combination** of all of these developments, has led to powerful synergies.[12] For nuclear facilities, the spin-offs of these technical advances are that nuclear safety has been further enhanced, processes streamlined and the economics improved. These advances have also contributed to the development of innovative nuclear systems, purported to be proliferation-resistant, safe and economical. Related work performed in the framework of the IAEA INPRO project and the multinational Generation IV projects thus have potential implications for non-proliferation, safety and economics of nuclear energy as a whole.

46. Technological developments have made concealment of non-peaceful uses at complex facilities technically less difficult. Conversely, Agency safeguards verification and other verification systems have benefited as well from most of these developments, in particular, in connection with material accountancy evaluation through information technology (IT), particle analysis, destructive and non-destructive measurements (chemistry) and surveillance (sensor technology and IT). In fact, real-time verification of most peaceful nuclear processes has now become a technical possibility and, indeed, a reality in cases where the IAEA has concluded that it is cost-effective and where governments have cooperated in their implementation.

47. An evaluation of the impact of these advances on a variety of aspects of the peaceful uses of nuclear energy, such as proliferation risks, safeguards, assurance of supply, energy planning security and economics, shows that:

a. Easier accessibility: proliferation risks have increased markedly in recent decades with the easier accessibility of sensitive nuclear technologies made available through clandestine supply networks that span the globe and by the dissemination of weapons design information.

b. Safeguards: technological advances have had a strong and positive influence, leading to increased safeguards effectiveness and efficiency. There is disagreement, however, as to whether this positive factor compensates fully the higher proliferation risks brought about by similar advances in technology, as noted above.

c. Assurance of supply and energy planning security: advanced technologies, with their promises of small-scale facilities and lower costs, encourage the pursuit of national facilities or regional MNAs may make them more attractive for achieving domestic or regional self-sufficiency in the fuel cycle. For smaller countries, such facilities make the possibility of national independence at a reasonable cost a more achievable goal.

d. Thus, in terms of economics, technology has made it possible to build smaller facilities, and this trend will likely continue; that is, for a given throughput and a given size, the costs have decreased. Nonetheless, economies of scale continue to apply; a multinational partnership at a higher throughput may provide even better economics than national facilities.

48. On the production side, enrichment to weapon-grade uranium using early generations of ultra-centrifuges seemingly has become less difficult, since documents on design, materials and process control of these early machines are more readily available. However, advanced designs to achieve a steady output at reasonable cost are still not available. Furthermore, the know-how and experience gained from some 20 years of development cannot be re-engineered or reverse engineered in only a few years. With regard to uranium conversion, to or from uranium oxides to UF_6, the know-how has become readily available.

[12] These synergies resulted for example in the development and implementation of advanced automatic measurement stations for IAEA safeguards verifications, where motion sensors trigger non-destructive measurements and video films of objects moved through the space of interest and the automatic and encrypted transmission of these data to IAEA HQ, via the internet.

49. Safeguards verification of the peaceful use of enrichment plants and associated conversion processes has become very effective as a consequence of the advances in chemistry and sensor technology referred to above. Real time verification of an enrichment facility can be achieved at a pro rata cost lower than one thousandth of the cost of producing one "separative work unit" (SWU).

50. Large-scale reprocessing installations using wet chemistry are now coming under IAEA inspection. The IAEA has defined the verification approaches and criteria to be applied. Verification of modern reprocessing facilities with complex chemical processes requires a very complex network of advanced sensors. Such verification is therefore costly, with an impact on IAEA's financial and human resources. The safeguarding of advanced reprocessing techniques, such as those based on pyrochemical processes, will be a challenge. Simpler and cheaper verification might be achieved when integrated plants are constructed with no outright separation of U, Pu and minor actinides.

51. With respect to fuel cycle facilities at the back end of the fuel cycle (spent fuel and related facilities), there are no major verification problems, since technological advances allow for efficient IAEA safeguards using real time verification for MOX and spent fuel and related facilities. The widespread implementation of the Additional Protocol will further accelerate this development by allowing access to locations beyond the usual "strategic points".

4.2 - Economics

52. This section summarizes generic economic considerations relevant for all multinational nuclear fuel cycle facilities. Additional economic considerations specific to different technologies (enrichment, reprocessing, storage and disposal) are addressed in the appropriate sections of the next chapter.

53. History and logic suggest that the more profitable a proposal, the easier will it be to recruit partners for its implementation. Economies of scale exist for most facilities in the nuclear fuel cycle, and the likelihood that multinational facilities will be larger than national facilities raises the possibility that economies of scale will generate simultaneous non-proliferation and economic benefits. The double incentive should make it easier to establish a multinational facility. Furthermore, hosting an MNA brings many benefits, such as large capital investment and the creation of jobs in the host country.

54. Economies of scale and economic benefits are not sufficient conditions for a multinational facility. Even where they exist, it can be very difficult, for the reasons outlined below, to structure incentives that will be attractive to all necessary partners. Moreover, a country bent on proliferation may not necessarily be dissuaded, even by a very lucrative MNA alternative.

55. As in any other commercial undertaking, the economic attractiveness of an MNA will be vulnerable to economic upsets or major shifts, whether due to markets, politics, accidents, or natural disasters. If so, hedges and insurance arrangements may be needed to enhance its economic appeal in spite of such possibilities. An MNA's attractiveness must also not be overly dependent on the future development of nuclear power, whether in expansion or in contraction, globally or regionally.

56. Different parties sometimes have different motivations and different expectations of the future. A successful MNA must dovetail these differences in ways that attract the participants necessary to deliver the desired economic and non-proliferation benefits. The costs of start-up, operations, liabilities and needed accumulating funds (e.g. for eventual decommissioning) must be allocated efficiently and equitably in the eyes of the participants. Acceptable dispute resolution provisions

must be included, and if universal, or very broad, participation is needed, compensation arrangements may be needed to assure that every party judges itself a net winner.

4.3 - Assurances of supply

57. Currently, the commercial market satisfies the demand for fuel services subject to government approval for exports. There is a diversity of commercial enrichment companies; enrichment capacity exceeds demand; and, based on current plans for the substitution of diffusion by centrifugation, capacity is likely to comfortably keep abreast of projected increases in demand in the medium term (e.g. until the end of the US/Russia agreement on HEU conversion to LEU). For other front end processes (such as conversion and fuel fabrication) the situation is similar. This equilibrium in the uranium market is likely to change only if the demand for nuclear power increases significantly, or in case of sudden disruption in supply.

58. However, there exists the risk that a State with uranium enrichment capacity may cut off supplies to other States to gain leverage for reasons that have nothing to do with non-proliferation concerns. Against that possibility, a country needing low enriched uranium for nuclear power plants may have an interest in alternative extra-market measures being in place to provide assurances of supply. Other than for the production of weapon-usable nuclear materials, possible motivations for building a domestic enrichment capability might include:

a. Reducing external dependence on foreign suppliers and achieving greater economic independence, e.g. when faced with a shortage of foreign currency or energy supplies,
b. Unfavourable experiences in the past and low confidence in existing suppliers,
c. National prestige and expected spin-offs for industrial and technological development; and
d. Possible technical advantage, allowing for lower production costs than existing facilities and for a commercial edge.

59. For any given country, none, some or all of these motivations might be relevant. Establishing a multinational arrangement may provide inducements for States to join the MNA and forgo their domestic capability. Nevertheless, an international external assurance of supply would address the first two motivations in this list, and further inducements (not necessarily nuclear) would address the third. A State that pursues a domestic capability may not necessarily be doing so to create the option of acquiring nuclear weapons but might be pursuing technological or market gains.

60. As recalled in the previous chapter, both INFCE and CAS extensively examined the issues surrounding assurance of supply, without coming to any agreed conclusions or agreed mechanisms to provide such assurance. For *customers*, the steps identified included supplier-customer risk-sharing arrangements, diversification of suppliers and customers, customised contracts, the early conclusion of commercial contracts, improved information exchange, and the maintenance of a sound market for spot transactions. For *governments*, they included the more uniform, consistent and predictable application of export and import controls; mechanisms to manage changes in non-proliferation policy that would minimise the risk of any resulting disagreements interfering with supplies; and the establishment of a common approach to non-proliferation (which could take the form of common practices, joint declarations, codes of conduct or other instruments) rather than individual prior consent rights.

61. In general, and in particular for MNAs, any prior consent rights should be based *primarily* on non-proliferation considerations, in particular compliance with safeguards agreements, in order to provide a credible assurance of supply. And the opinion of the IAEA should be decisive in this regard. Of course, other legitimate reasons could be invoked for prior consent rights, such as poor

safety records, poor physical security and insolvency. Quite evidently from the evidence at hand, individual prior consent rights will not be readily given up by those holding them, unless the concerns are adequately covered by suitable MNA agreements.

62. INFCE discussed two possible multilateral mechanisms for supply emergencies, while emphasising the importance of smoothly functioning competitive markets as the best assurance of supply. The two back-up mechanisms were identified: a "safety net" network and an international fuel bank.

63. CAS followed up these INFCE discussions and produced periodic forecasts of uranium supply and demand. But CAS was unable to reach a consensus on both the "Principles for international nuclear energy cooperation and nuclear non-proliferation" and on "Emergency and back-up mechanisms", and went into formal abeyance. A key stumbling block was the inability to reach agreement on broad principles of international cooperation, and the rejection of any piecemeal agreement by many parties without nuclear power programmes.

Fuel Guarantees: Physical and Virtual Fuel Banks, and the IAEA as guarantor

64. Theoretically a **physical fuel bank** could store material in any of several post-enrichment forms. Inter alia, some key storage possibilities are: enriched UF_6 as a solid or gas, UO_2 powder, UO_2 pellets or finished fuel assemblies. Some important advantages and disadvantages of each are the following.

65. Uranium hexafluoride (UF_6) is the most flexible form of storage and the most desirable for users as it can be easily stored for long periods and transported without difficulty as and when needed. UF_6 is the least proliferation-resistant form of enriched uranium, the chemical form most suitable to boost reactor-grade UF_6 to weapons-grade.

66. UO_2 powder degrades more quickly than either UF_6 or pellets, making it a less suitable storage form for a fuel bank. But it is more proliferation resistant since a reduction and conversion process would be required prior to clandestine enrichment. A stockpile in a fuel bank containing a variety of enrichments could be considered to augment supply assurance.

67. UO_2 pellets are physically and chemically stable, a storage option more suitable for a fuel bank. However, the pellet design depends on the reactor type. This would be a disadvantage for a fuel bank meant to efficiently provide assurances of supply for a range of different reactors.

68. Storage of a variety of finished fuel assemblies is, in practice, incompatible with the way in which the current nuclear power plants operate since fuel assemblies are effectively tailor-made reflecting the unique operating design and history of a reactor core for which they are intended as well as continuing improvements in fabrication technology, burn-up rates and fuel economics.

69. A "safety net" network, or **virtual fuel bank**, would be based on commitments by countries and/or firms to make their enriched material available as agreed, either directly or through the IAEA. Commitments from suppliers could be made to the Agency, and the State receiving the enriched material would receive it from the Agency. There are precedents for such an Agency role: in the 1960s, in several cases, legal ownership of research reactor fuel was transferred from the US to the IAEA and subsequently to the recipient country, without physical control of the fuel by the Agency. The Agency could maintain 'assurance of supply' arrangements with a number of suppliers and maintain access to funds to allow prompt payment to suppliers before collecting payment from a recipient country.

70. A virtual fuel bank would be closely associated with the existing industrial partners, and would not disturb the market. However, the fuel bank's material would be located in precisely those

countries that are trusted least by those seeking assurances of supply. A virtual bank would therefore need a real footing in several trusted locations. Also needed: strong oversight and review through international management and boards, on which supplier States would be represented, and effective and modern Agency verification to keep close track of all materials.

71. Prima facie evidence suggests that if a prospective fuel bank could improve efficiency, and therefore profits, the industry would have already created it. Economically speaking, a multilateral fuel bank would be more about sharing costs than about profits.

72. Recently, the "United Nations High Level Panel" has formulated a recommendation[13] on the involvement of the IAEA. In its report, the Panel urged "*that negotiations be engaged without delay and carried forward to an early conclusion on an arrangement, based on the existing provisions of articles III and IX of the IAEA statute, which would enable IAEA to act as a guarantor for the supply of fissile material to civilian nuclear users. Such an arrangement would need to put the Agency in a position to meet, through suppliers it authorized, demands for nuclear fuel supplies of low enriched uranium and for the reprocessing of spent fuel at market rates and to provide a guarantee of uninterrupted supply of these services, as long as there was no breach of safeguard or inspection procedures at the facilities in question*".

73. Depending on the specific agreement negotiated, the term "guarantor" could cover a variety of roles to be played by the IAEA: judging whether the conditions for supply are being met, including assessing the non-proliferation status of the recipient; activation of any decision to supply, including requesting governments/companies to fulfil supply obligations; acting as a broker between supplier and recipient; and overall management of the arrangement. In all such "guarantor" functions, the Agency will need to rely on the cooperation of other actors, i.e. governments and companies.

74. However, the IAEA need not be involved in a multilateral fuel bank, although it would provide a stronger assurance if it were. A fuel bank could instead be nothing more than an agreement between suppliers, with or without government backing. Both alternatives are examined in more detail in the next chapter.

75. Concerns about assurances of supply have existed since the 1960s and, even in 2005, is a central element of national nuclear policies. The secure availability of nuclear energy rests on assurances of supply of nuclear material, equipment, services and support for those having nuclear plants. Domestic solutions, which are the privilege of a few States, are not available to others. In an age of growing interdependence and globalisation, the drive for self-sufficiency is diminishing as an element of national economic policies. In this perspective, MNAs may represent an effective alternative to national solutions, depending upon conditions of the assurances of supply of fuel and/or services that are credible and viewed by the potential clients as dependable, reliable and economical.

76. The fundamental conditions that potential MNA partners may demand are worthwhile restating:

a. Diversity of suppliers participating in the MNA;

b. The willingness of a sufficient number of suppliers to grant to the MNA generic consent for the transfer of the respective goods and services assuming of course that basic premises with be fulfilled (non-proliferation credentials, physical security, export controls and safety records);

[13] Report of the Secretary General's High level Panel on Threats, Challenges and Change - A more secure world: Our shared responsibility, United Nations, New York (2004).

c. The availability from such suppliers of significant amounts of fissile material free of "national flags" and free of prior consent rights from other parties;

d. Sufficient reserve capacity of the respective fuel and services to cover supply emergencies, in a setup equivalent to the mandatory national oil reserves held by Organization for Economic Cooperation and Development (OECD) members under the auspices of the International Energy Program of the International Energy Agency;

e. A credible, timely, non-discriminatory and reliable decision-making mechanism for the release of replacement supply;

f. A pricing mechanism for the provision of substitute fuel and services in case of emergency that is deemed fair and that leads to prices not significantly higher than those set by the market; and

g. A neutral and fair process for determining whether a recipient that has lost its original supplier is in good standing with its non-proliferation commitments.

4.4 - Legal and Institutional

77. The establishment and operation of an MNA needs to be founded on an appropriate legal base. Such a facility could have as its legal basis:

a. an international agreement alone (as exemplified by Eurochemic);
b. national legislation (as exemplified by EURODIF);
c. any combination of a and b (as exemplified by Urenco).

78. In practical terms, there is little difference between a legal basis consisting of an international agreement alone and one consisting of an international agreement and national legislation (although the difference between the two will vary depending on the extent to which the requirements of the agreement are expressed in general or specific terms: the more general the terms of the agreement, the greater the difference). This is so because, normally, national legislation is needed to implement the terms of an international agreement. Two exceptions to this general rule are: for a State in which existing legislation is sufficient to enable the implementation of the treaty; for a State in which an international agreement automatically becomes part of national law upon its entry into force for that State. However, even in these two cases, regulations (which are a form of legislation) may be needed for full and effective implementation.

79. With respect to the second possible legal basis, that is, national legislation alone, a State could, of course, enact legislation for the establishment and operation of an MNA. However, while a State has jurisdiction to require that the legislation be observed by any person or entity making use of the services provided by the facility, that State has no jurisdiction to enforce the observance of such requirements outside its territory (without the consent of the State in whose territory the person or entity is located, or unless the person or entity has assets against which legal action can be taken in the territory of the legislating State). Further, in the absence of a binding international agreement, a State would be free to repeal or change such legislation.

80. If an international agreement were to form the, or part of the, legal basis, for an MNA, the following issues related to form and procedure would need to be addressed:

a. whether all States would be entitled to become parties to the agreement (i.e. a universal agreement) or only those States in a given region (or, for that matter, whether it could be

bilateral); and in that context, whether regional agreements could be concluded and brought into force more quickly than a universal agreement;

b. how the agreement would enter into force: if the agreement were to be multilateral, whether it should enter into force upon adherence to it by the host State and one or more other State(s);

c. whether the agreement should refer only to existing facilities of a stated technology (e.g. all existing enrichment facilities in the States party to the MNA), or should refer only to future such facilities, or should refer to other facilities of the fuel cycle;

d. whether it would be feasible to have an approach based on an agreement between the States in which the relevant facilities are located, together with separate agreements between that group of States and each State in which persons or entities within the latter's territory are to receive the services of the facility or facilities.

81. The agreement(s) or national legislation would also have to address, among others, the following substantive issues:

a. what entities may participate in or benefit from the MNA (e.g. governments; governmental entities; private entities);

b. the conditions for participation in the MNA, may include:

i) the application of appropriate IAEA safeguards pursuant to an INFCIRC/66-type agreement or an INFCIRC/153-type agreement, and an additional protocol based on INFCIRC/540 (Corr.)[14], in the territory of all recipients of the output (e.g. services, material) of the facility. Accepting INFCIRC/66-type safeguards as a sufficient condition of supply, however, would imply a fundamental change in the policies of all NPT States Parties involved in the respective MNA;
ii) the application of appropriate safety and physical protection measures in the territory of all recipients of the output of the facility;
iii) an undertaking by each State to prohibit within its territory activity "parallel" to that of the facility (e.g. any other enrichment activities); and, if agreed by a State or group of States, restricting research and development on such technology to the MNA entity;

c. the conditions upon withdrawal from the agreement for legitimate reasons must be agreed upon;

d. the sanctions to be applied with respect to any breach of sub-paragraphs (b) and (c) above;

[14] INFCIRC/66-type agreements normally apply to particular supplied nuclear facilities, nuclear material, equipment and/or non-nuclear material. They can also apply to transferred technological information. The duration of such agreements is related to the period of actual use of the safeguarded items. The agreements also contain provisions to the effect that, notwithstanding termination of the agreement, safeguards continue to apply to supplied nuclear material and special fissionable material produced, processed or used in or in connection with supplied items until the IAEA has terminated safeguards on such material. Equivalent provisions apply with respect to the continuity of safeguards on supplied items. In cases where a State has in force an INFCIRC/66-type agreement before becoming a party to the NPT (and concluding an INFCIRC/153-type agreement), the INFCIRC/66-type agreement remains in force but provision is made for the application of safeguards under the INFCIRC/66-type agreement to be suspended while the INFCIRC/153-type agreement remains in force. If a State has concluded only an INFCIRC/153-type agreement and a supplier State required that an INFCIRC/66-type agreement also be concluded, there would be no legal impediment. However, whether the IAEA would conclude an INFCIRC/66-type agreement under such circumstances is a matter for decision by the IAEA's Board of Governors.

e. how joint decisions are to be taken with respect to the supply of material or services, and agreed circumstances justifying a denial of supply (e.g. for reasons unrelated to non-proliferation, such as failure to fulfil commercial conditions);

f. how disputes (commercial or otherwise) are to be settled, including issues of forum and jurisdiction);

g. whether the MNA should be treated as an independent international legal entity, and, if so, the nature and extent of any privileges and immunities that are to be accorded to it in the host State and in other participating States;

h. how and by whom decisions relating to the operation of the MNA are to be taken;

i. how and by whom the activities of the MNA are to be financed; and

j. what provisions should be made in case of insolvency of the MNA.

82. While many, if not most, of the above substantive issues may also be addressed in commercial contracts, these may not be sufficient since they would be binding only on the commercial parties thereto.

83. With the above in mind, and based on the premise that, to be attractive for further consideration, an MNA should be designed to lessen proliferation, security and safety concerns while providing assurances of supply of nuclear fuel in return for restraints in the use of sensitive technology, the following three categories of options for multilateral approaches are considered and assessed in the following chapter:

(a) Options involving assurances of services not involving ownership of facilities

i: Additional assurances of supply by suppliers: These assurances could take different forms, such as longer-term contracts or contracts with more favourable incentives. This might require all supplier-States agreeing to amend any national legislation and international commitments which impose prior consent conditions.

ii: International consortium of governments: This could take the form of an actual or virtual fuel bank to which governments would ensure the availability of material. Alternatively, supplier governments could physically hold the material, subject to an agreement on how it is to be distributed.

iii: IAEA-related arrangements: The IAEA could physically hold title and distribute the material. Alternatively, the IAEA could conclude an agreement with a State or States to provide the material or services on instruction from the IAEA. Countries most concerned with assurances of supply would likely prefer a role by the IAEA. For the Agency to play this role, suppliers would need to relinquish all prior consent rights to material provided to or by the Agency; for some, this might be a difficult and complicated decision. In addition, the IAEA might decline to provide material in certain circumstances (such as non-compliance in safeguards, poor nuclear safety records, poor physical security or insolvency).

(b) Options involving the conversion of national facilities to multinational facilities

This would entail the conversion of an existing national facility to one subject to international ownership and management. It could be based on an arrangement in which all partners share the technology or one in which access to the technology is limited to the technology holders.

(c) Options involving the construction of new facilities

i: The Urenco model: The original model involved the sharing of technology with all partners involved in the construction of a new facility. More recently, the model has been extended to allow construction of a facility in a third country, without providing this country access to sensitive technology.

ii: The EURODIF model: Although the partner(s) would all have a financial share in the ownership and production of the facility, the technology holder(s) would not give the other partner(s) access to the technology nor permit them to participate in the operation of the facility.

4.5 - Non-proliferation and security factors

84. Since nuclear non-proliferation concerns are the driving force behind the present interest in devising multilateral approaches, it is necessary to ensure that any models for such approaches strengthen, not weaken, the non-proliferation regime. The transfer of sensitive technologies should be kept to a minimum and subject to stringent control. Related issues to be resolved from a non-proliferation and security perspective might include: siting of the multilateral facilities or operations; security of materials, facilities and transport; handling and storage of wastes; take-back of spent nuclear fuel; timely supply of fresh fuel and timely removal of spent fuel; and common legally binding non-proliferation undertakings.

85. As an alternative to multilateral approaches to prevent additional states from developing enrichment and/or reprocessing capabilities, other approaches have been suggested. One proposes that nuclear facilities should be constructed in those States that already possess other such facilities. This idea has led to debate over discriminatory regimes. Some academic literature has suggested that Article IV of the NPT could be amended. However, such as approach is widely considered to be unacceptable. Others argue that economics have meant that there is no need for enrichment and reprocessing MNAs. However, some believe that political assurances will also be needed.

Safeguards implementation

86. The concerns evoked by clandestine supply networks, the availability of and increasing access to nuclear technology, and the possibility that some countries may be tempted to use such technology for non-peaceful purposes cannot be ignored, particularly given past evidence that a few countries have either been in fundamental breach of, or have not complied with, their NPT safeguards obligations. Hence, the importance of the IAEA's strengthened safeguards system and of the Additional Protocol. There are primarily two risks, among others, addressed by IAEA safeguards: diversion of fissionable materials from declared facilities and construction of undeclared fuel cycle facilities built with technology transferred from the declared programme. In the latter case, the Additional Protocol helps to provide credible assurance regarding the absence of undeclared nuclear material and activities.

87. With respect to MNAs, safeguards implementation by the IAEA should take into account the special positive nature of a multinational nuclear facility. Participants, whether private or governmental, would be committed to transparency and openness through the continuous presence of a multinational staff. Flows of materials would be mostly between partners to the MNA. The MNA agreement could even be stronger in this respect. This additional layer of international oversight would be recognised by the IAEA, possibly allowing thereby a reduction of the safeguards verification effort.

88. This situation was anticipated by the drafters of the Model Safeguards Agreement agreed by the Board of Governors in 1971, a model that has been adopted for almost all safeguards agreements concluded since then. Paragraph 81 of the model safeguards agreement (INFCIRC/153) lists criteria to be used by the IAEA for determining the actual number, intensity, duration, timing and mode of routine inspections of any facility. Its paragraph (d) covers the following criterion: "*International interdependence, in particular, the extent to which nuclear material is received from or sent to other States for use or processing; any verification activity by the Agency in connection therewith; and the extent to which a State's nuclear activities are interrelated with those of other States...*".

89. In its report to the Director General in May 2004, the Standing Advisory Group on Safeguards Implementation (SAGSI) referred to Para. 81 of INFCIRC/153 and noted that a large number of facilities receive nuclear materials from, and send nuclear materials to, other States, and also that many facilities employ multinational staff whose activities are interrelated with those of other States. SAGSI confirmed that the IAEA should give appropriate recognition to international interdependence under the so-called "State level approach", an approach that would include consideration of State-specific factors such as the level of cooperation with the IAEA on safeguards implementation in the State, including consideration of openness and transparency; and the presence of a supportive and effective State System of Accounting for and Control (SSAC) of nuclear material. This context is relevant for MNA joint facilities.

Security and physical protection

90. Besides non-proliferation and safeguards factors per se, the physical protection of nuclear materials and related facilities has always been a matter of great importance. This importance has grown, due to the apparent increase in non-State actor interest in acquiring these materials. Nevertheless, no international treaty mandates that States possessing nuclear material to enforce physical protection and security measures. The NPT requires safeguards on nuclear material in NNWS Parties and that necessitates the establishment of a State System of Accounting and Control (SSAC), but physical protection is not an attendant requirement. In practice, SSAC's controls, Agency inspections and the Agency's review of national accounting help to some extent to provide physical security of the nuclear material under safeguards. However, Agency inspectors are not required explicitly to verify physical protection. When the IAEA system of safeguards for NNWS was established in 1971-1972, physical protection standards were only "recommended", and no agreement was possible among the States to make these standards mandatory.

91. The agreed and recommended standards were published in 1975 as INFCIRC/225, and have been since then regularly upgraded under IAEA auspices. The latest INFCIRC/225 document recommends that each State establish and periodically re-evaluate "design basis threats" for its facilities, as well as conduct exercises to test whether guards, sensors and other protection measures are adequate. The document includes detailed provisions on protecting nuclear power reactors as well as stored nuclear materials from sabotage.

92. The 1980 Convention on the Physical Protection of Nuclear Material (CPPNM) required physical protection standards but these apply only to nuclear materials for peaceful purposes that are in international transit or in temporary storage as part of international transport. Thus, the CPPNM applies only to civilian nuclear material and contains no verification provisions. The result is that there is a wide variation in physical protection standards from State to State. A process is underway to strengthen the CPPNM to include domestic use, storage and transport of civilian nuclear materials and the protection of nuclear facilities against sabotage. The proposed amendments do not cover nuclear material in military use or related military facilities.

93. From the security perspective, all multilateral nuclear fuel cycle approaches will face the requirement of being integrated within the existing international nuclear non-proliferation and

security arrangements in order to elicit the confidence of participating and other States. The challenge will be to ensure that a multilateral nuclear arrangement can be established with high standards of physical security and of MPC&A (material protection, control and accounting). However, MNAs may provide benefits in this context by encouraging peer group reviews of security issues.

Chapter 5 - Multilateral options for technologies

94. As noted in the Foreword, this report will follow a pattern as to the task at hand. The previous chapter dealt with the broad, ***cross-cutting factors*** relevant to multilateral nuclear arrangements and independent of any particular step of the fuel cycle. This chapter will consider the various steps (enrichment, reprocessing, spent fuel disposal and storage), first to review their ***specific factors*** and then to tackle the main task of the mandate, namely to define the ***specific options*** associated with one particular technology of the fuel cycle.

95. Whether for uranium enrichment, spent fuel reprocessing, or spent fuel disposal and storage, the search for MNA ***options*** revealed a logical way to catalogue, analyse and assess them. In essence, an MNA can span the whole field between existing market mechanisms and a complete co-ownership of fuel cycle facilities. As a result, the following pattern has been adopted:

Type I: Assurances of services not involving ownership of facilities:

a) Suppliers provide additional assurances of supply
b) International consortium of governments
c) IAEA-related arrangements

Type II: Conversion of existing national facilities to multinational ones

Type III: Construction of new joint facilities

96. Once a pattern has been chosen to catalogue and analyse the various MNA options, a method of assessment remains to be selected. The Group has opted to do so by simply reviewing and listing the **pros** and **cons** associated with each option. Pros and cons are defined relative to a national facility under current safeguards. The next step, which is the formulation of criteria allowing some sort of ranking (best, average, poor) according to stated factors such as non-proliferation, economics or assurance of supply, was not systematically attempted in view of the large number of parameters to be considered, including the nature of the fuel cycle and the relative importance of nuclear power to different countries.

97. In articulating the pros and cons, however, it became clear that what might be considered a "pro" in the context of one factor, such as non-proliferation, might be perceived as a "con" when considered in the context of another factor, such as assurances of supply. As a consequence, it was decided to make a short-hand reference, in the tables of pros and cons, using the "labels" A to G, to a number of central elements described in the following Section 5.1.

5.1 - Elements of assessment

98. Assessing the options and their pros and cons, implies an underlying choice of relevant elements, which will guide the analysis and the comparison of options. Among the cross-cutting factors considered in the previous chapter, two stand out as primary deciding factors in the consideration of multilateral approaches, namely "**Assurance of non-proliferation**" and "**Assurance of supply and services**". Both are recognised overall objectives for governments and for the NPT community. In practice, each of these two objectives can seldom be achieved fully on its own. History has shown that it is even more difficult to find an optimum arrangement that will satisfy both objectives at the same time. As a matter of fact, multilateral approaches could be a way to satisfy both objectives.

Key Elements

99. The **non-proliferation value** (*Label A*) of a multilateral arrangement is measured by the various proliferation risks associated with nuclear facilities, whether national or multilateral. These risks include the following:

a) **Diversion of materials** from an MNA is primarily related to the level of multilateral involvement in its functioning. Because of the different nationalities and interests that exist in a multinational team, it is reasonable to assume that a deeper involvement of such a team ensures a diminishing risk of diversion – provided that there is no collusion.

b) **Breakout scenarios and clandestine parallel programmes** are related to the siting of the MNA facility in a country that is not a technology holder. The risk level for the breakout scenario depends upon the effectiveness of contractual enforcement provisions. The risk of a clandestine programme is increased because of the cover provided by the declared facility (i.e. know-how, procurement, R&D and obscuring enriched uranium traces). However, with effective safeguards and an Additional Protocol in place, these risks could be mitigated.

c) **Diffusion** of proscribed or sensitive technologies from MNAs to unauthorized entities is predominantly related to the participants degree of access to these technologies. More extensive access to sensitive technologies increases the risk of their diffusion.

d) **Security risks.** The risk of theft of nuclear, and especially of fissile, materials depends upon the effectiveness of the facility's physical protection system. A well-guarded MNA, which replaces a wider dispersion of sensitive fuel cycle facilities, has a clear advantage in that respect.

100. The "**Assurance of supply**" **value** (*Label B*) of a multilateral arrangement is measured by the associated incentives. They include the following:

a) **Guarantees** –The political, commercial, legal and technical credibility of the guarantees provided by suppliers, governments and international organisations;

b) **Economics** – Economic benefits that would be gained by countries participating in multilateral arrangements. Examples could include competitive fuel service costs resulting from the basic advantages of MNA, such as economies of scale, indirect start-up cost savings, or other economical incentives driven by political considerations.

c) **Political and Public Acceptance** – In some instances, MNAs may lead to a wider acceptance of a nuclear project in the host country. In others, e.g. final disposal, the impact could well be negative for the host country, although beneficial for others.

d) **Security and Safety** – To enhance acceptance, any nuclear project, whether national or international, must satisfy proper standards of material security (that is accountability and physical protection), and of nuclear safety for the design and operation of facilities. Here also, the multilateral dimension provides an additional level of confidence, thereby indirectly improving the assurance of supply related to such facilities.

Other Elements

101. While "**Assurance of non-proliferation**" or "**Assurance of supply and services**", are the key elements of assessment, other elements – or issues of interest – are important, mainly insofar as they contribute to the two key elements. They include:

102. Siting – Choice of host country (*Label C*). There are three basic options for hosting fuel cycle facilities under multilateral arrangements:

a) Special arrangements – legal structures limiting national jurisdiction on the site of MNA fuel cycle facility (*"extra-territorial" status*);
b) States that are already technology holders;
c) States that are not technology holders.

The nature of safeguards agreements applicable to a location would also be an important factor. Furthermore, the host country will have to be acceptable to partner countries.

103. Access to technology (*Label D*). Multilateral options might also vary in the extent of access to technology that they permit:

a) Full access;
b) Assembly and maintenance know-how;
c) Operational know-how;
d) None.

104. Multilateral involvement (*Label E*). Multilateral options may also offer various levels of involvement for the participating States:

a) Minimum: Supply-only arrangement;
b) Ownership: sharing ownership of the facility;
c) Management: taking part in the management of the facility;
d) Operation: participating in the operation of the facility;
e) Maximum: Joint research and development, design and construction of facilities.

105. Special safeguards provisions (*Label F*). Each multilateral option should have safeguards provisions that define the measures to be taken to ensure that no proliferation occurs. Such measures might include:

a) Expanded facility-specific safeguards agreement, covering not only nuclear materials, but also functionally essential components of an MNA facility;
b) Additional Protocol;
c) Special safeguards arrangements;
d) "Continuity of Safeguards" for the facility and the nuclear material and components in connection with the breakout scenario, breach of contract, or a voluntary dissolution of the arrangement.

106. Non-nuclear inducements (*Label G*). These may prove vital in securing the willingness of certain States to restrict or forego the possession of indigenous nuclear fuel cycle facilities. Incentives may include:

a) Trade benefits
b) Security arrangements (regional/international)
c) Security guarantees/assurances
d) Assistance in the development of the (non-nuclear) energy sector

Such incentives would be country-specific. An understanding is needed as to what factors are applicable to the partner-State and what factors are applicable to the host-State, since they would differ for each.

107. Finally, it can be noted that with the help of such elements, multilateral options can be compared among themselves, as well as with purely national arrangements.

5.2 - Uranium enrichment

108. The term 'enrichment' is used in relation to an isotope separation process by which the abundance of a specified isotope in an element is increased, such as the production of enriched uranium from natural uranium or heavy water from plain water[15]. An enrichment facility separates isotopes of uranium to increase the relative abundance, or concentration, of ^{235}U in relation to ^{238}U. The capacity of such a facility is measured in Separative Work Units (SWU).

Technologies

109. Uranium must be enriched if it is to be used in certain reactor types and in weapons. This means that the concentration of fissile ^{235}U must be increased before it can be fabricated into fuel. The natural concentration of this isotope is 0.7%, but a concentration of around 3.5% is usual to sustain a chain reaction in the most common commercial nuclear power plants. Some 93% enrichment is customary for weapons and for naval propulsion. Yet, naval propulsion is possible with only 20%, or even less. The enrichment process is not linear, since as much separative work is needed between 0.7% and 2% as between 2 to 93%. This means that the enrichment work up to the weapon level is reduced to less than one half and the amount of uranium feed to less than 20%, when commercial enriched uranium is readily available.

110. Of the techniques for increasing the concentration of ^{235}U, seven are of particular importance:

111. *Gaseous Diffusion* - This was the first method of enrichment to be commercially developed. The process relies on a difference in the mobility of different isotopes of uranium when they are converted into gaseous form. In each gas diffusion stage, uranium hexafluoride gas (UF_6) is pumped under pressure through a porous nickel membrane (installed sequentially in a cascade), which causes the lighter gas molecules containing ^{235}U to pass through the porous walls of the tube more rapidly than those containing ^{238}U. This pumping process consumes large amounts of energy. The gas that has passed through the tube is then pumped to the next stage, while the gas remaining in the tube is returned to lower stages for recycling. In each stage, the concentration of ^{235}U /^{238}U is increased only slightly. Enrichment to reactor grade requires over a thousand stages.

112. *Gas Centrifuge* - In this type of process, uranium hexafluoride gas is forced through a series of rapidly spinning cylinders, or centrifuges. The heavier ^{238}U isotopes tend to move towards the wall of the cylinder more than the lighter molecules containing ^{235}U. The gas nearer the centre is removed and transferred to another centrifuge for further separation. As it moves through a succession of centrifuges, the gas becomes progressively richer in the ^{235}U isotope. Electricity requirements for this process are relatively low compared with gaseous diffusion, and as a consequence this process has been adopted for most new enrichment plants.

113. *Aerodynamic Separation* - The so-called Becker technique involves forcing a mixture of hexafluoride gas and either hydrogen or helium through a nozzle at high velocity and then over a curved surface. This creates centrifugal forces that act to separate the ^{235}U isotopes from the ^{238}U. Aerodynamic separation necessitates fewer stages to achieve comparative enrichment levels than gaseous diffusion, but this process still requires large amounts of electricity and is not generally considered economically competitive. In a significantly different aerodynamic process from the Becker process, a mixture of uranium hexafluoride and hydrogen is spun centrifugally in a vortex within a stationary wall centrifuge. Withdrawal of the enriched and depleted streams takes place from both ends of the tubular centrifuge in an arrangement somewhat similar to the revolving centrifuge. An industrially sized plant of 250000 SWU/a capacity for a maximum 5% ^{235}U

[15] See IAEA Safeguards Glossary.

enrichment operated within South Africa for almost 10 years, but also suffered from excessive energy consumption and was closed down in 1995.

114. *Laser Enrichment* - The laser enrichment technique involves a three stage process; excitation, ionization and separation. There are two techniques to achieve these effects, the 'Atomic Approach', and the 'Molecular Approach'. The Atomic Approach is to vaporise uranium metal and subject it to a laser beam at a wavelength that excites and ionises the ^{235}U atoms, but not the ^{238}U atoms. Then, an electric field sweeps the ^{235}U atoms onto a collecting plate. The Molecular Approach also relies on differences in the light absorption frequencies of uranium isotopes, and begins by exposing molecules of uranium hexafluoride gas to infrared laser light. ^{235}U atoms absorb this light, thereby causing an increase in their energy state. An ultra-violet laser can then be used to break up these molecules and separate the ^{235}U. This process appears to have the potential to produce very pure ^{235}U and ^{238}U, but overall efficiencies and recombination rates remain to be proven. It should be noted here that the molecular process can only be used to enrich uranium hexafluoride and is not suitable to "clean" high burn-up Pu metal as is possible in principle with the atomic process that can enrich both U and Pu metal. The molecular process is, therefore, marginally more non-proliferation friendly than the atomic laser process.

115. *Electro-Magnetic Isotope Separation (EMIS)* - The EMIS process of enrichment is based on the fact that an electrically charged atom, travelling through a magnetic field, moves in a circle whose radius is determined by the ion's mass. EMIS is achieved by creating a high current beam of low energy ions and allowing them to pass through a magnetic field created by giant electro-magnets. The lighter isotopes are separated from heavier isotopes by their differing circular movements. This is an old technique, used in the early 1940s. Coupled with modern electronics, it can serve for the production of weapons-grade materials, as Iraq had attempted to do in the 1980s.

116. *Chemical Separation* - This form of enrichment exploits the fact that ions of these isotopes will travel across chemical 'barriers' at different rates because of their different masses. There are two methods to achieve this: the method developed in France of solvent extraction; and the process of ion exchange used in Japan. The French process involves bringing together two immiscible liquids in a column, giving an effect similar to that of shaking a bottle of oil and water. The Japanese ion exchange process requires an aqueous liquid and a finely powdered resin, which slowly filters the liquid.

117. *Plasma Separation* - In this process, the principle of ion cyclotron resonance is used to selectively energise the ^{235}U isotope in a plasma containing ^{235}U and ^{238}U ions. The plasma flows through a collector of closely spaced, parallel slats. The large-orbit ^{235}U ions are more likely to deposit on the slats, while the remaining plasma, depleted in ^{235}U, accumulates on an end plate of the collector. The only countries known to have had serious plasma experimental programs are the United States and France. In the US, development was dropped in 1982. The French project was suspended around 1990, although it is still used for stable isotope separation.

118. Thus far, only gas diffusion and centrifugation have reached commercial maturity. To a different degree, all seven techniques are more or less sensitive in terms of proliferation, since they can be used in a clandestine programme to produce high enriched uranium from natural uranium or from low-enriched uranium regardless of cost. However, the signatures will be different, affecting the likelihood of detection.

Historical background

119. Multinational arrangements have been somewhat more successful in uranium enrichment than in similar efforts in the field of spent fuel reprocessing. In part, this is because reprocessing technology is much more widely known, and uses more conventional industrial techniques than enrichment, which was originally, and exclusively, based on the very sophisticated, industrially complex and highly classified gaseous diffusion technology. The newer centrifuge enrichment technology is still subject to the kinds of uncertainties that make joint ventures involving cost- and risk-sharing more appealing.

120. The two uranium enrichment consortia, Urenco and EURODIF, are institutional expressions of the movement towards a European indigenous enrichment capability. In spite of initial difficulties, they came to represent two different economic and industrial models of multinational ownership and operation, neither of which was established for explicitly non-proliferation purposes, but both of which contributed to that end[16].

121. Urenco is the more complex of the two organisations, embracing enrichment facilities in three countries: the United Kingdom, Germany and the Netherlands. Based on the Treaty of Almelo, Urenco owns and operates gas centrifuge enrichment facilities in the three participating States, helps to coordinate research and development (at first jointly, then individually, and then collectively once again), assures equal access to developments in centrifuge technology by any of the members, and executes contracts for the sale of services to third countries with the unanimous agreement of the participants.

122. The main driving force behind the setting up of the Urenco organisation in the early 1970's was commercial; it was clear to the British, Dutch and German shareholders that developing the centrifuge technology and exploiting it solely for their respective national power programmes would bring security of supply, but not at a competitive cost. Clearly, the best way forward was to cooperate and share development and operating costs, firstly to supply their joint national requirements, and subsequently, if the outcome was a more competitive position, to be able to sell enrichment services commercially outside their domestic markets.

123. Nonetheless, for a business and a technology as sensitive as uranium enrichment, there were other political considerations, that helped to drive the decision to set up such an international programme. The three governments believed that the type of international organisation that could be established – with multinational organisation and management, together with trinational political oversight and control rights – would prevent the proliferation of technology and materials. It is also worth recalling that, at that time, there were significant political sensitivities to building a plant to enrich uranium in Germany; this was avoided by building the first German- owned capacity in Holland, as a joint Dutch/German-owned facility, operated by an international team.

124. From the start, EURODIF involved five participating countries - France, Italy, Spain, Belgium and Iran - but only one enrichment facility, located in France. Unlike Urenco, which is oriented towards an external market, EURODIF was intended to serve the domestic fuel requirements of its members. The level of investment of each member corresponded to its percentage share of the product, and sensitive barrier technology was held by only one member: France. Thus, while excluding the transfer or sharing of sensitive technology, EURODIF did provide European participants with an assurance of supply, and an equity share in a production enterprise utilising proven advanced technology. Unlike Urenco, EURODIF has never been a manufacturer of enrichment equipment.

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[16] SCHEINMAN, L. "The Nuclear Fuel Cycle: A Challenge for Non-proliferation"; Disarmament Diplomacy; March/April 2004.

125. Neither of the two enrichment consortia have been trouble-free. Urenco has faced difficulties both in terms of technology and investment. It was originally intended that Urenco would develop a single centrifuge technology that would be exploited on a centralised basis. The participants, however, had already made heavy investments in technology development at the time Urenco was established, and they were unwilling to forego this investment in favour of a common technological approach. As a result, they decided in 1974 to permit each of the shareholders to continue developing their own technology, in order to determine which one would best apply for new common facilities. Insofar as investment was concerned, Urenco plants were to be built with equal ownership and investment by the three partners, regardless of location. By the mid-1970s that formula was revised in favour of a two-thirds national/one-third partners' investment arrangement, in response to differences among the shareholders regarding the timing for new facilities and the appropriate marketing strategy. Subsequently, the formula was revised again to reflect a 90% national ownership in Urenco facilities. Later, all facilities were brought once more under a single ownership with full multinational management and operation.

126. EURODIF's problems have been of a somewhat different nature. Changes in the pace of national nuclear power programmes have affected the timing of requirements for enriched uranium, particularly in Italy, which had taken a 23% share in EURODIF production at the time the organisation was created. Unable to absorb its share of the production, yet required to take and pay for it, Italy sought to alter its relationship to the consortium. Iran was faced with the same problem, and received back the major portion of its initial investment. These changes markedly increased the French share, further reducing the multinational character of the enterprise.

127. This and the Urenco experience underscore the economic vulnerabilities of multinational arrangements, a lesson for other countries contemplating similar ventures. A multinational fuel cycle strategy, just like a national one, must rest on a solid economic justification in order to be successful.

Current status

128. Enrichment facilities, under IAEA safeguards, presently exist in the following countries: Argentina, Brazil, China, Germany, Iran, Japan, Netherlands, and the United Kingdom. Furthermore, enrichment facilities not under safeguards exist in France, India, Pakistan, the Russian Federation and the USA.

129. The next decade will see something very unusual in the nuclear fuel cycle: all of the world's commercial enrichment enterprises will be engaged at the same time in re-building and to a lesser extent expanding their industrial capacities. Old plants will be decommissioned and new ones will be added as new Parties come into the picture[17]. The annual world demand in 2004 was about 38 million SWU, expected to grow to some 43 million SWU in 2020[18], with higher projections of up to 52 million SWU.[19] The current production capacity amounts to 50 million SWUs per year.

▶EURODIF

The Georges Besse Gas Diffusion Plant (GDP), now operated by Areva, has been running in recent years with an output of approximately eight million SWU/year from a nominal capacity of 10.8 million SWU/year. Investment in new GDPs, however, will not be competitive with the latest generation of centrifuge, which is why the Georges Besse plant will be replaced by centrifuge capacity in the years ahead. The replacement will be based on the Urenco technology. A new

[17] RWE NUKEM, Market Report, November 2004

[18] AREVA, France; communication to the Expert Group.

[19] The Global Nuclear Fuel Market: Supply and Demand 2003 – 2025, World Nuclear Association, London (2003).

Quadripartite Agreement, focusing on the protection of the technology, will ensure that the basic Urenco arrangements (the Treaty of Almelo, between the British, German and Dutch Governments) are also respected in the joint venture with Areva in France. The installed capacity of the new French enrichment plant will be some 7.5 million SWU/year as of 2015. In spite of this cooperation, Areva and Urenco will remain competitors in the market of enriched uranium, as explicitly requested by the European Commission.

►Urenco

The three enrichment plants of Urenco (Gronau in Germany, Almelo in the Netherlands and Capenhurst in the UK) have a total capacity of 6 million SWU/year. The capacity will increase slowly to the level of 8 million SWU/year by year-end 2007.

One of the more closely followed projects in the enrichment world is the current project of Urenco and its American utility partners (Louisiana Enrichment services, LES) to site and build an enrichment facility in the US to diversify the national SWU sources of supply. Urenco has estimated (based on its own experience) that a plant can be made operational within about two years of the start of construction. The first enriched uranium from the new American facility is thus expected to roll off the line as early as the last quarter of 2008. Full capacity will be 3 million SWU/year by the year 2013.

►United States Enrichment Corporation (USEC)

USEC is responsible for the marketing of the 500 tonnes of high enriched uranium released from the Russian weapon stockpile, transformed into low-enriched uranium before shipment to the United States. For the future, unlike Areva and LES, USEC is banking on a new technology that has never operated on a commercial scale. The USEC centrifuge machines will incorporate a number of enhancements that modern industrial techniques and computer technology now make possible. Each one of them is said to be about 12 metres tall and roughly 50 centimetres in diameter, far larger than Urenco's latest model. This represents major engineering challenges and makes for a rather technically risky nuclear project. The payoff, according to USEC, is that they will be the most economical centrifuges ever built. The current plan calls for capacity of one million SWU/year in 2010 and 3.5 million SWU/year at "full production" in 2011.

►Rosatom

The Russian enrichment production runs extremely well using fairly basic "subcritical" short machines that operate reliably with little maintenance. The Russian current enrichment capacity is about 20 million SWU/year. Freshly mined uranium in Russia falls short of the annual requirement to fuel Russian-type reactors, both domestic and foreign. The shortfall is made up in several ways, including using reprocessed uranium, the return of feed from the Russian-American deal on high enriched uranium, and tails-stripping activities involving both foreign and possibly domestic sources of depleted uranium. The total separative capacity is expected to reach 26 million SWU/year a couple of years beyond 2010.

►Japan Nuclear Fuel Limited (JNFL)

The Uranium Enrichment Plant is operating with a capacity of 1.05 million SWU/year. A centrifuge with performance of 2.5 to 3 times higher than conventional ones is under development. In the future, the capacity is planned to be increased by 1.5 million SWU/year, meeting approximately one-third of the enrichment needs of nuclear power plants in Japan.

Economics

130. Little information is available on the economics of enrichment. Most transactions of enrichment services are made through long-term contracts. The spot/secondary market price for a SWU has been moving from a $60-80 range in the late eighties to $90-110 now. With respect to gaseous diffusion, the electricity cost component may be close to $60, since it takes some 3000 MWe to produce 10 million SWU, assuming a cost of 3 cents/kWh. Centrifuge production should offer a comfortable margin, even when taking into account the higher capital costs.

131. Uranium enrichment facilities are extremely capital intensive (centrifugation even more than diffusion). Therefore, from the strict short-term economic perspective, such facilities should serve large reactor fleets or be commercially competitive on the world market to make economic sense.

Assurance of services

132. Separative work capacity in the world is expected to exceed demand for the next 10 years, and thereafter remain abreast of demand. With suppliers eager to do business, there is hardly a reason to doubt the ability of the market to provide adequate assurance of enrichment services. Yet, among the suppliers themselves, those with large nuclear power programmes – such as France and the United States – want to maintain a self-sufficient supply capacity. For smaller countries, the MNA route could offer economic and strategic advantages in buttressing regional assurances of supply.

Legal and institutional

133. Under this heading, the cases of Urenco and EURODIF may again serve to illustrate the related legal and institutional arrangements that need consideration.

134. At Urenco, political responsibilities are kept separate from industrial and commercial operations. The political aspects of the activities of the Urenco Group are controlled by the intergovernmental Joint Committee, which was set up under the agreement of the Treaty of Almelo (signed and ratified by all three governments in 1971). This Joint Committee has jurisdiction over those areas of international concern, including safeguards, classification and security, the suitability of enrichment service customers, the transfer of technical information and technology to third parties, and the siting of major facilities. The Joint Committee governs the way political and security aspects of any technology joint ventures are managed. For example, in the case of the LES partnership venture to build a centrifuge enrichment plant in the USA, the three governments of the Joint Committee reached agreement with the US government on the Quadripartite Agreement. This agreement sets out the required arrangements under which Urenco classified information and/or technology is to be transferred into the USA, in order to enable the plant to be licensed, constructed and operated, (and the control of any information flowing back to Urenco from the US plant). The commercial viability of any such project is not covered; it is entirely a matter for the Urenco management and its shareholders.

135. Through the late 1970's and 1980's, Urenco operated as three separate national companies working together as a partnership; each country had the ability to design, develop and manufacture centrifuges, and build, commission and operate the plant. Since the restructuring of the Urenco Group in 1993, the organisation has been run on an international basis from the Group Headquarters in the UK, with plant design concentrated in the UK, centrifuge manufacture in the Netherlands, and centrifuge R&D in Germany.

136. The Almelo Treaty allows for any of the countries to formally withdraw from the Treaty, upon one year's notice and after the first ten years of its operation, albeit with some difficult commercial negotiations. If this were to happen, one could then envisage a new, national organisation, which could take charge of the national plant. However, although the continued operation of existing enrichment plants would not be compromised, the international division of responsibilities now within the Urenco Group would make this more difficult/expensive to sustain. The most difficult aspect would be the ability to manufacture and assemble centrifuge components for new capacity, and to re-establish R&D capability for future development.

137. Therefore, Urenco represents a good management model for multinational arrangements and demonstrates the viability and utility of separating the political and business decision-making authorities, a division of authority that has never disrupted the industrial and operational responsibilities of the organisation.

138. In comparison with Urenco, EURODIF is straightforward: management, operations, and technology remain under the national control of the host state. Its potential value as a model for non-proliferation is correspondingly greater. On the other hand, precisely because of the managerial, operational, and technological limitations that this approach imposes on all but the host nation, its appeal may be limited to States which have little interest in the opportunity to participate in management or to have access to advanced technology, but which are content to have access to fuel supply on a timely, predictable, and economically attractive basis.

139. With no transfer or sharing of sensitive technology, EURODIF was able to provide its European partners with irrevocable security of supply. The EURODIF model, however, has one distinct disadvantage whenever a strategic redirection in technology is necessary, as is now the case with EURODIF itself going from diffusion to centrifugation. Although the other shareholders outside the host country may participate in a broad decision to adopt entirely new technology or marginally change the existing technology through upgrading, they have no access to a detailed technical risk assessment of the future new or upgraded technology and they have to rely totally on the host country's own internal and confidential assessment. Partners with a significant investment may perceive this as an unacceptable risk and the Urenco model has a distinct advantage in this regard.

Non-proliferation and security

140. Today, if cost is of no concern, small centrifuge facilities can be built in most industrialised countries. In order to produce one significant quantity (SQ) of high enriched uranium (that is the approximate amount required for manufacturing a nuclear explosive device taking into account unavoidable losses), there is no need for plant sizes comparable to the large commercial facilities discussed earlier in this chapter: a good-sized office conference room would accommodate the required number of centrifuges. The task is even simpler if enriched uranium is at hand: as noted earlier, at the 3.5% enrichment level, used by nuclear power plants, six-tenths of the separative work needed for weapon-grade uranium has already been carried out. At the 20% enrichment level, used by research reactors, nine-tenths of the separative work needed for weapon-grade uranium has already been carried out. Once an enrichment facility has been established, it is estimated that it could take as little as a few months to produce enough HEU for one SQ, should the operators so desire and without any external restraint.

141. Enrichment facilities represent a particular challenge for international verification, because of the veil of secrecy that enshrouds such facilities. On the one hand, the facility owner is often reluctant to let outsiders have a close look at his centrifuges, to protect his legitimate trade secrets. On the other hand, international inspectorates prefer to keep their own inspectors away from

proliferation-relevant know-how. Verification must sometimes follow indirect routes, the enrichment level in the piping and in the environment being a good indicator of misuse of a facility, so that together with in-situ inspections, modern technology – in particular the physico-chemical analyses of trace particles - offers a number of powerful tools capable of detecting anomalies on known nuclear sites.

142. The safeguards approach developed for gas centrifuge uranium enrichment plants subject to safeguards and operating at a stated uranium enrichment of 5% or less involves inspection activities both inside and outside cascade areas. Inspections outside the cascade hall are focused on verifying declared flows and inventories of nuclear material to detect the diversion of declared uranium. Inspections of cascade areas, known as Limited Frequency Unannounced Access (LFUA)[20] are designed to detect the production of uranium at an enrichment level which is higher than that declared, while protecting the sensitive technical information related to the enrichment process. The LFUA regime, inter alia, secures access with short notice for IAEA inspectors to the cascade area of the plant concerned. Inspection activities to be implemented within the cascade area include visual observation, radiation monitoring and non-destructive assay measurements, environmental sampling, and application and verification of seals. The activities to be performed and the frequency of access to the cascade area depend on the design and operation specifics of the plant.

143. With respect to multinational enrichment facilities, past studies have drawn no specific conclusions as to their possible implications for non-proliferation since, at the time, this technology was of little concern. Firstly, and insofar far as safeguards are concerned, the MNA concept implies fewer larger facilities. Having fewer sites to watch means, in turn, that with a given amount of resources – a given safeguards budget – the IAEA is in a position to monitor more carefully. Secondly, in terms of proliferation risks, a joint facility with multinational staff places all participants under a greater degree of scrutiny from peers and partners, all of which strengthens non-proliferation and security. By their very nature, such MNAs have the potential to deter a "breakout" by the host partner. A countervailing factor, of course, is the possibility that international cooperation may increase proliferation risks (misuse of know-how, of procurement and of R&D). In this context, it would seem that the Urenco model is quite appropriate for partners having already developed their own individual know-how, while the EURODIF model has the upper hand when most participants/partners have not already done so.

Options for multilateral approaches for enrichment

144. This section suggests pros and cons associated with different approaches to assuring the supply of enrichment services, using the standard typology defined earlier.

Type I: Assurances of services not involving ownership of facilities

a. Suppliers provide additional assurances of supply

145. This would correspond to enrichment plant operators, individually or collectively, guaranteeing to provide enrichment capacity to a State whose government had in turn agreed to forego building its own capacity, but which then found itself denied service by its intended enrichment provider for unspecified reasons.

[20] see IAEA Safeguards Glossary.

Pros*	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A)	*1. The cost of maintaining reserve idle capacity (or a fuel bank), if required, needs to be assigned among the suppliers (B)*
2. Ease of implementation, few participants, no new ownership arrangements required (B)	*2. For some, States with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B)*
3. Reliance on a well-functioning market (B)	*3. Credibility of 'assurance' commitments unclear in the case of private firms (B)*
4. No additional safeguards financial burden on the IAEA (B)	*4. Maximum dependence on "prior consent rights" of supplying countries (B)*

By the very nature of the nuclear business worldwide, any guarantee from a supplier would have the implicit or explicit agreement of that supplier's government. However, the governmental agreement would apply only to the supplier under its jurisdiction. This model may be understood as a "private fuel bank" (See also Section 5.3).

b. International consortium of governments

146. In this case, it is a consortium of governments that would guarantee access to enrichment services; the suppliers would simply be executive agents. The arrangement would be a kind of "intergovernmental fuel bank". The mechanism might involve legislation establishing a government claim on such capacity under specified circumstances. Alternatively, it might be a contract, under which a government buys guaranteed capacity under specified circumstances. Different States might use different mechanisms. Most pros and cons are shared with the preceding case:

Pros	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A)	*1. Difficult negotiations among many governments and suppliers (B)*
2. Cost of reserve-keeping can be borne by governments rather than by the suppliers (B)	*2. For some, States with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B)*
3. Reliance on a well-functioning market (B)	*3. Remaining dependence on "prior consent rights" attached by supplier States (B)*
4. No additional safeguards financial burden on the IAEA (A)	*4. Existing property rights must be taken into account (B, E)*
5. Consortium guarantees more reassuring (B)	

c. IAEA-related arrangements

147. This is a variation of the preceding option, with the IAEA acting as the anchor of the arrangement. Essentially, the Agency would function as the guarantor of supply to States in good standing under the NPT and which are willing to accept the requisite conditionality (which would need to be defined, but which would likely need to include foreswearing a parallel path to enrichment/reprocessing plus acceptance of the Additional Protocol). The IAEA might either hold title to the material to be supplied or, more likely, act as guarantor, with back-up agreements between the IAEA and supplier countries to fulfil commitments made by the IAEA effectively on their behalf. These assurances in turn might need to be supplemented by standby arrangements

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement – F: Special safeguards provision – G: Non-nuclear inducements

whereby one nuclear supplier would step into the shoes of another should the first fail to perform. In effect, the IAEA would be establishing a default mechanism, only to be activated in instances where a normal supply contract had broken down for other than commercial reasons, in which case supply would need to be in conformity with the previously agreed criteria.

148. The suggested pros and cons are therefore similar. An additional pro reflects the composition of the IAEA: its membership is broader than that of a commercial consortium. Furthermore, there is the IAEA's track record, reputation, credibility and relevant experience. The viability of the arrangement might nonetheless require a sufficient number of suppliers to grant prior generic consent for the transfer of the respective materials and services.

Pros*	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A)	*1. Diverse and potentially conflicting interests and priorities of IAEA. Difficult negotiations among many governments, suppliers' membership. Uncertain liability exposure of the IAEA (B)*
2. Cost of reserve-keeping can be borne by the IAEA rather than by the suppliers (B)	*2. For some, countries with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B)*
3. Reliance on a well-functioning market (B)	*3. Remaining dependence on "prior consent rights" of supplying countries, except if they recognise the IAEA as bona fide end-user (B)*
4. No additional safeguards financial burden on the IAEA (A)	
5. IAEA guarantees more reassuring (B)	

149. Several questions can be raised with respect to the IAEA and its special status as an international organisation subject to the control of its Member-States. Any guarantee provided by the IAEA would require approval by its Board of Governors. For a recipient country, this amounts to 35 governments to deal with instead of one or a few. Therefore, what would be legitimate grounds for denial on the part of the IAEA besides safeguards, safety and security? For States seeking a supply guarantee, what would be the real value added of an IAEA guarantee? Questions requiring further clarification also relate to whether procedures for arbitration or legal settlement would be available after a decision by the Board, and whether the IAEA would carry a commercial liability exposure.

Type II: Conversion of existing national facilities to multinational ones

150. Converting a national facility to international ownership and management would involve the creation of a new international entity, which would operate as a new competitor on the world enrichment market. Thus a number of the suggestions in the table below reflect the pros and cons of an international entity in such a situation, independent of the related technology. Others reflect the fact that most of the existing facilities are in NWS or non-NPT States.

151. The EURODIF model would be the most likely model for the conversion of an existing national facility into a multilateral arrangement. For such a model, the pros and cons are:

* A: Non-proliferation – B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provision - G: Non-nuclear inducements

Pros*	Cons
1. No new construction required. No further dissemination of know-how; hence reduced proliferation risks (A, D)	*1. Several facilities would likely be needed in sufficiently politically diverse countries to provide needed assurances (B)*
2. When additional safeguards measures are introduced in facilities where they do not now exist, non-proliferation is strengthened (A, F)	*2. Existing property rights must be taken into account (B, E)*
3. Potential strengthening of proliferation resistance through international management (A, E)	*3. Difficulties of international management, especially with the distinctive burden of providing assurances of supply (B)*
4. Potential pooling of international expertise and resources (B, D, E)	*4. Potential proliferation risks due to diffusion of international know-how (A)*

***Type III*: Construction of new joint facilities**

152. The two historical precedents for the construction of a new multinational enrichment facility are Urenco and EURODIF. New joint construction was also the focus of the IAEA's 1975-1977 Regional Nuclear Fuel Cycle Centre (RFCC) Study, albeit in the context of reprocessing, and is thus of general relevance here. Most of the suggested pros and cons below stem from this context.

Pros*	Cons
1. Strengthening of proliferation resistance through multinational oversight, management and staff, with less opportunity for diversion, theft and loss, and breakout (A, E)	*1. Higher proliferation risks due to broader access to know-how (unless the EURODIF model is followed) (A, C, D, E)*
2. Pooling of international technical expertise and financial resources (B, D)	*2. Uncertain commercial competitiveness in a market where there is no shortage of supply or possible market disturbances by subsidized facilities (B)*
3. Economies of scale (B)	*3. Difficulties of international management, as experienced by Urenco (E)*
4. Fewer larger enrichment centres mean fewer sites to safeguard (A, C)	*4. Difficulties with long-term cost sharing, as experienced by EURODIF (E, F)*

153. The planning of a new uranium enrichment facility would be a challenging undertaking, requiring large human and financial resources, in which many considerations would be intertwined. On the non-proliferation side, these considerations are: diversion risks; clandestine parallel programmes; breakout from agreements and from the NPT; and safeguards arrangements. On the business side, such considerations are: siting; economics; political and public acceptance; access to technology; partners' involvement in operation; and non-nuclear commercial and trade agreements. However, in the case of enrichment, there are the existing examples of Urenco and EURODIF to refer to.

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement – F: Special safeguards provisions – G: Non-nuclear inducements

5.3 - Spent fuel reprocessing

154. Reprocessing facilities dissolve and process spent nuclear fuel to chemically separate uranium and plutonium from fission products. The recovered uranium and plutonium can be recycled in mixed-oxide (MOX) fuel in nuclear power plants to generate additional energy, thereby making more complete use of uranium resources and reducing enrichment requirements. Reprocessing also facilitates final waste disposal by reducing the volume of high level waste and removing plutonium. Reprocessing is an international business with facilities in France, the Russian Federation and the United Kingdom willing to accept foreign spent fuel for reprocessing. With the exception of Russian reprocessing of Russian origin spent fuel, current laws in these three countries require that all final waste be eventually returned to their countries of origin.

155. The reasons given for civilian reprocessing are: recycling the fissionable components – plutonium (e.g. as MOX) and uranium – and for radioactive waste management. Thus there is a close connection between reprocessing and MOX fuel fabrication: it is important to match these activities to avoid the build-up of separated plutonium. This chapter therefore looks at reprocessing facilities in isolation, and also in connection with their complementary MOX fabrication facilities.

Technologies

156. All operating commercial reprocessing plants, and the one under construction at Rokkashomura, use the PUREX process and 'chop-leaching' technique. After storage for cooling, a fuel assembly's end-fittings are sheared off, the fuel rods are chopped into pieces and dissolved in nitric acid, and cladding hulls and other residue are removed. A multistage solvent extraction process, using tributyl phosphate (TBP) as a solvent, is generally used, first, to separate uranium and plutonium from fission products and minor actinides and second, to partition the uranium and plutonium from each other. The end products from the process are uranyl nitrate solution, plutonium nitrate solution and raffinate solution containing fission products and minor actinides.

157. At the Tokai and Rokkashomura plants in Japan, the immediate next steps are denitration to produce uranium oxide powder (UO_3) and co-denitration to produce mixed uranium-plutonium oxide powder (UO_2-PuO_2). Plutonium nitrate solution is immediately mixed with uranyl nitrate solution without separation. These are the forms in which the uranium and plutonium are stored. At the Thorp plant in the UK and the La Hague plants in France, the separated uranium and plutonium are stored as UO_3 and PuO_2. Eventually, the plutonium oxide or mixed oxide powder is shipped to fuel fabrication and then returned to the owner as MOX fuel assemblies. Currently the uranium oxide is largely stored, although Urenco re-enriched recycled uranium in the past and some is still sent to Russia for re-enrichment.

158. The RT1 plant in Russia accepts WWER-440 spent fuel and HEU spent fuel from fast reactors, research reactors and submarine reactors. The principal product is uranium oxide, which is recycled in RBMK fuel. Plutonium oxide is stored.

159. Research to improve existing reprocessing technologies covers advanced PUREX processes and other aqueous processes, the THOREX process for separating ^{233}U in thorium-based fuel cycles, non-aqueous processes including volatility and reductive extraction processes, and pyrochemical processes.

160. Pyrochemical separation relies on electro-refining techniques, in which spent fuel is dissolved in a molten salt electrolyte, and the useful material is then precipitated onto electrodes. Although they have not yet been developed beyond the laboratory or pilot plant scale, pyrochemical techniques are potentially applicable to most fuel forms. Moreover, because they

make it more difficult to completely separate uranium, plutonium and minor actinides from fission products, pyrochemical processes are also considered more proliferation resistant than the PUREX process. Incomplete separation maintains high deterrent radiation levels. However, it also makes the output of pyrochemical processes less suitable for recycle in MOX fuel in thermal reactors, restricting its use largely to fast reactor fuel.

161. Several States are also conducting substantial research on partitioning and transmutation (P&T) as part of processing spent nuclear fuel. P&T, however, has no immediate implications related to non-proliferation.

Historical background

162. The earliest fuel reprocessing efforts were devoted to recovering plutonium from irradiated fuel for military use. However, the initially rapid expansion of civilian nuclear power and high projections of future growth, coupled with a very conservative understanding of the long-term availability of uranium resources, argued strongly for reprocessing spent fuel to recycle fissile plutonium and uranium. The argument was especially strong in countries with limited uranium resources, such as France, India Japan, the United Kingdom and to a lesser extent the USSR.

163. The most efficient way to use reprocessed fuel is in fast reactors. Fast reactors have a long history, with the first nuclear electricity ever produced coming from a fast reactor, EBR-1, in 1951. Additional fast reactors, including some fast breeder reactors, subsequently came on line in the USSR, the UK, the USA, France, Germany, India and Japan. New reprocessing plants were planned (and some completed) in Western Europe and North America. However, the early economic incentives for reprocessing and recycling diminished, partly because of the slowdown in nuclear capacity growth starting in the 1970s, partly because uranium resource estimates continually rose and partly because of secondary sources from the release of some military uranium and from the re-enrichment of depleted uranium. The changed economic incentives limited the introduction of fast reactors and of reprocessing.

164. Only one fast reactor, BN-600 in the Russian Federation, currently operates as a power reactor, and it uses not reprocessed plutonium fuel, but fresh high enriched uranium (HEU) fuel. India, however, has just begun construction (October 2004) of a 500 MWe prototype fast breeder reactor at Kalpakkam, and there is ongoing research in a number of countries.

165. The principal historical example of a multinational arrangement is the European Company for the Chemical Processing of Irradiated Fuels (Eurochemic), created in 1959 by 13 European countries. Eurochemic was initially seen by its member countries as a way to pool financial and intellectual resources, and to gain national expertise in an expensive but promising industry. Its facility at Mol, Belgium reprocessed civilian power reactor fuel from 1966 to 1975. At the time of project termination, nuclear growth was slowing, there was overcapacity in the reprocessing business, European enthusiasm for international organisations like Eurochemic had dimmed, national chemical industries in member countries preferred to develop their own experiments with national government aid and Eurochemic's dependence on multiple governments for funding and decision-making made it especially difficult to compete in what was anyway a difficult competitive business.

166. A second international reprocessing initiative (which contributed to the demise of Eurochemic) was the United Reprocessors Gesellschaft (UNIREP), created in October 1971 by British, French and German reprocessors. It followed a FORATOM (European Atomic Forum) recommendation to rationalise investment in order to establish a 'viable industry' in Europe given

the then prevailing overcapacity. Wolff (1996)[21] describes UNIREP as "trilateral commercial co-operation in the form of an oligarchic cartel. Its immediate aim was to divide the European reprocessing market between the British and French plants until their capacity was saturated. At this point, a large German plant would take over." In the end, however, UNIREP never built a plant.

Current status

167. Growth in reprocessing capacity has been limited. For civilian nuclear power plants, France has two large reprocessing facilities at La Hague owned and operated by Cogema; the UK (BNFL) has two and the Russian Federation (Rosatom) one. Three smaller facilities operate in India (BARC) – as well as one facility for thorium separation – and one in Japan (JNC). Except for the Japanese facility (Tokai), all currently operating plants are in either NWS or non-NPT States. All are owned directly by governments or by companies controlled by governments. The total nominal capacity available for reprocessing civilian spent fuel is approximately 5000 tonnes of heavy metal per year (tHM/a).

168. About one third of the spent fuel that has been discharged from Power Reactors has been reprocessed up until today, a significant fraction of which is used for MOX fuel for LWRs. The rest is in interim storage. By the end of 2003, 78 000 tonnes of spent fuel had been reprocessed. The plutonium content of MOX fuel generally ranges from 4 % to 40 % depending on the capacity and type of reactor. In recent years the world's civilian power reactors generated approximately 89 tonnes of Pu per year in spent nuclear fuel; approximately 19 tonnes of Pu per year were separated out of spent nuclear fuel; approximately 13 tonnes of Pu were fabricated into MOX each year. The approximate amount of plutonium subject to Agency safeguards at the end of 2003 is included in Table 1 along with other materials subject to Agency safeguards.

[21] WOLFF, J.-M., "EUROCHEMIC (1956-1990) Thirty-five years of international co-operation in the field of nuclear engineering: The chemical processing of irradiated fuels and the management of radioactive wastes", OECD, Paris (1996).

Table 1

Approximate quantities of material subject to Agency safeguards at the end of 2003

Type of Material	Quantity of material (t)		
	Comprehensive safeguards agreements[a]	INFCIRC/66[b]	Nuclear weapon States
Plutonium[c] contained in irradiated fuel	626.54	33.4	95.9
Separated plutonium outside reactor cores	12.7	0.1	72.8
Separated plutonium in fuel elements in reactor cores	14.2	0.3	0
HEU (equal or greater than 20 % U-235)	21.7	0.1	10
LEU (less than 20 % U-235)	45480	3069	4422
Source material[d] (natural or depleted uranium and thorium)	88130	2124	11998

[a] Covering safeguards agreements pursuant to NPT and/or Treaty of Tlatelolco and other comprehensive safeguards agreements.

[b] Excluding installations in nuclear weapon States; including installations in Taiwan, China.

[c] The quantity includes an estimated 90 t of plutonium in irradiated fuel, which is not yet reported to the Agency under the reporting procedures agreed to (the non-reported plutonium is contained in irradiated fuel assemblies to which item accountancy and C/S measures are applied).

[d] This table does not include material within the terms of subparagraph 34(a) and (b) of INFCIRC/153 (Corrected).

169. The worldwide operational nominal capacity for MOX fuel fabrication is approximately 300 tHM/a. In 2001-2002, MOX fuel requirements for LWRs were approximately 190 tHM/a. MOX fuel was loaded on a commercial basis in 36 LWRs in Europe, and TAPS-1 and -2 in India operated with several MOX fuel assemblies on a trial basis. Although it is possible to use MOX in any LWR, MOX is currently more expensive than fresh uranium oxide fuel, and no substantial increase in MOX fuel requirements is expected in the near term. Only France plans to license more PWRs for MOX. Japanese plans to load MOX fuel at LWRs have been delayed. In addition to this use in commercial LWRs, MOX fuel was used in Japan at the FUGEN advanced thermal reactor, prior to its being shut down in 2003, and the Joyo fast breeder reactor. It is also used at the Phenix reactor in France and in the experimental BOR-60 fast breeder reactor in Russia, and a few experimental fuel assemblies with MOX have been used at BN-600.

170. Construction of the new commercial reprocessing facility built at Rokkashomura in Japan started in 1993. Uranium commissioning began in 2004, active commissioning with actual spent fuel will begin in the course of 2005, and commercial operation is scheduled to begin in 2006. The Rokkashomura plant is unique in that the IAEA has been able to monitor and verify all stages of construction, a factor now considered essential for effective safeguards for any new reprocessing plant.[22]

[22] Report of the LASCAR Forum: Large Scale Reprocessing Plant Safeguards, STI/PUB/922, IAEA, Vienna, 1992.

171. Looking to the future, uranium prices have begun to rise in the last few years, and medium-term projections of nuclear capacity are regularly revised upwards. Credible long-term scenarios for nuclear power still range from a global phase-out in this century to a vast expansion. In fact, a number of countries are seeing a significant expansion of nuclear power, with a concurrent need for reprocessing and the use of MOX and, for countries committed to a high degree of nuclear fuel cycle independence, for fast breeder reactors.

Economics

172. Insights into the economics of multinational reprocessing based on the PUREX process come both from the experience of Eurochemic and UNIREP and from relevant studies. The principal IAEA study, the Regional Nuclear Fuel Cycle Centres study[23], focussed on the back end of the fuel cycle and more specifically on reprocessing. Its principal substantive motivation was the anticipated economies of scale in reprocessing facilities, but the study also addressed health, safety, environmental and non-proliferation issues.

173. The key result was as expected. A regional fuel cycle centre using the PUREX process would be profitable using cost estimates, interest rates, etc. as developed in the study. The calculations showed substantial economies of scale in building and operating reprocessing facilities. The investment in a regional centre could be 40-60% lower than for national facilities in the case of countries with fairly large nuclear power programmes. For States with small nuclear power programs, the regional cost could be a third or even less of the cost for a national facility. The time necessary to recover capital costs and start turning a profit could be shortened by ten years. The study also concluded that it was possible to evolve to this profitable operation by building the system from the core of existing or planned national installations at the time. The study perceived an incremental practical route from the then current situation to the goal of a regional centre.

174. The study also concluded that regional centres would offer safety, health and environmental advantages. These stemmed from the fact that big regional centres would require fewer sites. Fewer sites would mean fewer environmental impacts and fewer safety risks, and those two things together would mean fewer health impacts and risks, and also smaller cost. There was recognition that fewer, bigger sites would probably mean more shipping and transporting of nuclear material and, other things being equal, more transport would mean more chances for accidents. However, these risks were judged to have been outweighed by the risk reduction attributable to having fewer sites.

175. Despite the study's conclusively positive assessment, no regional fuel cycle centre has ever been built. The principal reason is that the economics changed. The study used a uranium price of $40 per pound U_3O_8 (in 1975 dollars), which appeared reasonable at the time, but the study also did a number of sensitivity analyses. Among other things, it concluded that, given the other economic parameter values that were assumed, even the regional reprocessing centre would be uneconomic if uranium prices were to drop as low as $30 per pound U_3O_8. In fact they dropped below $30 per pound U_3O_8 (in 1975 dollars) three years after the study was completed and have for almost a quarter of a century been below half that value. The spot price for U_3O_8 as of 10 January 2005 was back up to $20.70 per pound (or $7.40 in 1975 dollars).

176. The economics of reprocessing, or more generally the Pu-MOX fuel cycle, have often been debated. France and the United Kingdom now possess significant industrial experience in reprocessing and recycling. They have demonstrated that the cycle can be more or less

[23] REGIONAL NUCLEAR FUEL CYCLE CENTRES, Vol. 1, Summary, 1977 Report of the IAEA Study Project, IAEA, Vienna (1977).

competitive, depending on the price of uranium. In the long term, reprocessing makes it possible to recover valuable materials. In the short term, it reduces interim storage requirements, and in the medium term it reduces considerably the quantity and the radiotoxicity of waste to be disposed of. States with a significant nuclear programme and with a policy of energy independence have incentives to keep open the reprocessing and recycling strategy.

Assurance of services

177. World capacity to reprocess light water reactor fuel is expected to exceed demand for many decades, until plutonium recycling becomes necessary and more economical. In the meantime, with several suppliers ready to do business, the market stands ready to provide adequate assurance of reprocessing services.

178. A State that agrees to forego building its own reprocessing capability, but wishes to have its spent fuel reprocessed and to use the separated plutonium and/or uranium in MOX fuel, will want some assurance that the reprocessing services will be available as needed. Or the State will want an assurance that a package of reprocessing and MOX fabrication will be available as necessary. These are the scenarios envisioned in the listing below of options and possible pros and cons.

179. Various conditions for the assurance of future reprocessing services should be fulfilled in order for a multilateral facility to live up to non-proliferation premises and to assure services. The following release conditions should be incorporated:

a. Only MOX fuel and not separated Pu should be delivered or returned;
b. A reprocessing plant should have a co-located MOX fuel fabrication facility;
c. Just in time reprocessing, i.e. synchronisation of reprocessing and MOX fuel fabrication in order to prevent excess storage of separated plutonium;
d. Just in time MOX delivery, i.e. the delivery of fresh MOX fuel should be synchronized with the refuelling cycle in order to prevent the customer country from storing this fuel for longer periods of time.

Legal and institutional

180. In 1978, the Director General invited States to delegate representatives to an expert group to prepare "proposals for the establishment of schemes for the international management and storage of plutonium in implementation of Article XII.A.5 of the Agency's Statute". The expert group eventually completed its report in November 1982. Three alternatives for the release of Pu were considered, but ultimately no consensus was reached, and International Plutonium Storage (IPS) has never been established. A further study should evaluate release criteria, incorporating and reviewing the conditions mentioned in paragraph 179.

181. Eurochemic, the first multinational nuclear venture, was created in the 1950s under the auspices of the Nuclear Energy Agency (NEA) of OECD. Its termination in 1974, in the face of competition from larger national installations in member countries, has frequently been offered as proof of the weakness and improbability of effective multinational arrangements. Such an assessment, however, ignores certain other facts. Eurochemic was established to serve as a training centre in which reprocessing technologies could be acquired, various fuel types and techniques explored, and industrial experience developed. It was not designed as a means of averting the spread of reprocessing technology, or as an alternative to national development, even though some of its members (particularly the smaller States) may have hoped for the eventual emergence of a single European reprocessing consortium, which would provide a partnership of a

magnitude beyond their purely national capabilities. In terms of its mandate, Eurochemic was a success. It facilitated and launched the basis for industrial capability in a new technological field[24].

182. In view of its avowed purpose of technology transfer and the absence of any ban on parallel national technological development, Eurochemic would not be a particularly good model for non-proliferation-oriented multinationalism. On the other hand, ten years of such multinational training and development activity in a high technology area represents an experience and institutional dynamic which may provide important lessons for future ventures, particularly with respect to the scope of the mission; organizational arrangements; allocation of ownership shares and interest; financial obligation; and the degree of restraint imposed on participants regarding parallel activity. Indeed, Eurochemic's provision for an external control organ of participating State governments to deal with problems of common concern, while avoiding interference in operational activities, has been taken into account by subsequent multinational nuclear industrial ventures.

Non-proliferation and security

183. The principal proliferation concern associated with reprocessing plants is the capacity they provide a would-be proliferator to separate plutonium from spent fuel for a weapons programme. The security concern results from the possible presence at reprocessing plants (depending on specific reprocessing cycles) of separated plutonium that could be diverted or misused.

184. Verification of non-diversion at reprocessing plants relies on six major sets of inspection activities: design information verification (DIV), verification of inventory changes, verification of internal material flows, verification of interim inventories for timely detection, the examination of operator records and reports and annual physical inventory verification. Safeguarding reprocessing plants requires regular measurement and continuous monitoring during routine operations.

185. The effective and efficient safeguarding of a reprocessing facility is essential for assuring non-diversion of fissile material and to detect the misuse of the facility. Safeguarding a reprocessing plant is a costly and resource intensive task. In order to assure the highest level of certainty of non-diversion, the IAEA should be involved in the planning of the plant, as it was in Japan.

186. The additional establishment of regional arrangements could reduce the transportation risk for separated fissile material and enhance security, in comparison to intercontinental shipments, but could increase the transportation risk in comparison to national facilities.

187. In the future, new reprocessing processes may help strengthen proliferation resistance, while maintaining the Pu potential for use as fuel in fast reactors, by less complete separation of uranium, plutonium and minor actinides from fission products, which results in higher deterrent radiation levels. Further improvements, technological and otherwise, in monitoring and safeguards procedures may also strengthen the proliferation resistance of future facilities. Co-location of fuel fabrication plants, and perhaps reactors to burn the recycled fuel, could also help.

188. With respect to potential multinational reprocessing facilities, the IAEA Regional Nuclear Fuel Cycle Centres study concluded that a regional centre would have important non-proliferation and security advantages. First, given the PUREX process's economies of scale, the concept of regional centres implied fewer bigger centres than reprocessing built on national centres. Having fewer places to watch would mean that with a given amount of resources – a given safeguards budget – it would be possible to watch more carefully. Moreover, there would be fewer

[24] SCHEINMAN, L. "The Nuclear Fuel Cycle: A Challenge for Non-proliferation"; Disarmament Diplomacy; March/April (2004).

opportunities for diversion, theft and loss. Note that for potential future technologies with lower fix-costs, multinational facilities would not necessarily have these benefits. Second, joint operation puts each participant under greater scrutiny from peers and partners, an environment in which people tend to be more careful, attentive and rigorous, all of which strengthens non-proliferation and security.

189. A potentially countervailing factor, not mentioned in the IAEA study, is the possibility that international cooperation facilitates the international diffusion of reprocessing expertise. This would weaken proliferation resistance, given that the wider the expertise necessary to separate and handle weapons usable material is spread, the easier is proliferation.

Options for multilateral approaches for reprocessing

190. This section suggests pros and cons associated with different approaches to assuring the supply of reprocessing and subsequent fuel services, using the same typology as in other sections.

***Type I*: Assurances of services not involving ownership of facilities**

a. Suppliers provide additional assurances of supply

191. This corresponds to reprocessing plant operators, individually or collectively, guaranteeing to provide reprocessing capacity and/or MOX fuel to a country that had agreed to forego building its own capacity but then found itself denied service by its intended reprocessor for political reasons.

Pros*	Cons
1. No new plants required (A)	*1. The cost of maintaining available idle reserve capacity is unclear (B)*
2. Ease of implementation, few participants, no new ownership arrangements required (B,E)	*2. For some, States with reprocessing facilities may not be politically diverse enough to provide needed assurance (B)*
	3. Issues surrounding return of Pu and/or radioactive waste to customer country (A, B)
	4. Credibility of 'assurance' commitments unclear in the case of private firms (B)

192. Currently all reprocessing plants are State-owned. By the very nature of the nuclear business worldwide, any guarantee from a supplier would have the implicit or explicit agreement of the corresponding government. However, this type of agreement would bind only the supplier party.

b. International consortium of governments

193. In this case a consortium of governments would guarantee access to reprocessing capacity and to the return of MOX fuel. The suppliers would only be executive agents. The mechanism might be legislation establishing a government claim on such capacity under specified circumstances. Alternatively, it might be a contract by which a government buys guaranteed capacity, again under specified circumstances. Different countries might use different mechanisms.

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provision - G: Non-nuclear inducements

Pros	Cons
1. No new plants required (A)	*1. The cost of maintaining available idle reserve capacity is unclear (B)*
2. Consortium commitments may be more reassuring (B)	*2. The 'assured' capacity would be in existing facilities, and the countries with facilities may not be politically diverse enough to provide needed assurance (B)*
3. Cost can be borne by governments rather than industry (A)	*3. Issue of returning Pu and/or radioactive waste to customer country (A, B)*
	4. Existing property rights will have to be taken into account (B, E)

c. IAEA-involved arrangements

194. This is a variation of the preceding option with the IAEA as the key decision-making and administrative body of a consortium. The suggested pros and cons are therefore similar. Here, however, an additional pro reflects the composition of the IAEA: its membership is broader than that of a commercial consortium. For the IAEA to play its role, it would seem logical and necessary for the Agency to be freed of any further consent rights, assuming that consent rights could be subsumed into common mechanisms.

195. The mechanism might be legislation establishing an IAEA claim on such capacity under specified circumstances. Or it might be a contract by which the IAEA buys guaranteed capacity, again under specified circumstances.

Pros*	Cons
1. No new plants required (A)	*1. The cost of maintaining available idle reserve capacity is unclear (B)*
2. IAEA commitments may be more reassuring (B)	*2. The 'assured' capacity would be in existing facilities, and the countries with facilities may not be politically diverse enough to provide needed assurance (B)*
3. Cost of reserve-keeping can be borne by the IAEA rather than by suppliers (B)	*3. Diverse interests and priorities of IAEA membership (B)*
	4. Issue of returning Pu and/or radioactive waste to customer country (A, B)

The comments made previously for this type in the case of enrichment are also valid here.

***Type II*: Conversion of existing national facilities to multinational ones**

196. Converting a national facility to international ownership and management would involve the creation of a new international entity that would operate as a new competitor in the reprocessing market. Thus a number of the suggestions in the table below simply address the pros and cons of an international entity in such a situation, largely independent of reprocessing. Other items deal with the fact that, of the existing facilities, all except the two Japanese facilities are in NWS or non-NPT States. In many of those cases, safeguards will have to be introduced if they had not been applied before.

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement – F: Special safeguards provision – G: Non-nuclear inducements

Pros*	Cons
1. No new plants required (A)	*1. New safeguards practices would have to be 'back-fitted' to facilities in non-NPT States or NWS (A, B, C, E, F)*
2. Strengthening of proliferation resistance through international management and operating teams (A, E)	*2. Existing property rights must be taken into account (B, E)*
3. Pooling of international expertise and resources (B, D, E)	*3. Difficulties of international management as experienced by Eurochemic, especially with the unique burden of providing assurances of supply (B)*
	4. Potential proliferation risks due to international diffusion of reprocessing know-how (A, C, D, E)
	5. Several conversions would likely be needed in sufficiently politically diverse countries to provide needed assurances (B)
	6. Issue of returning Pu and/or radioactive waste to customer country (A, B)
	7. Possible increase in transportation requirements (A)

***Type III*: Construction of new joint facilities**

197. The one historical precedent for the construction of a new multinational reprocessing facility is Eurochemic. New joint construction was also the focus of the IAEA's 1975-1977 Regional Nuclear Fuel Cycle Centres. Most of the suggested pros and cons below come from the Eurochemic experience and the RFCC study. The new facility considered here would have the added burden of providing needed assurances of supply while successfully competing against reprocessing facilities without that burden. Therefore, a prerequisite for the construction of new facilities is the demand for additional reprocessing and MOX production.

198. It is presupposed that in the future a reprocessing plant and a MOX fabrication plant would be built next to each other. In such a case, only MOX fuel and not separated Pu will be subject to transportation.

Pros*	Cons
1. Fewer bigger reprocessing centres mean fewer sites to safeguard and fewer opportunities for diversion, theft and loss (A, B, F)	*1. Several such facilities would likely be needed in sufficiently politically diverse countries to provide needed assurances (B)*
2. Strengthening of proliferation resistance through international management and operating teams (A, E, F)	*2. Difficulties of international management as experienced by Eurochemic, especially with the unique burden of providing assurances of supply (B, E)*
3. Pooling of international expertise and resources (B, E)	*3. Potential proliferation risks due to international diffusion of reprocessing know-how (A, C, D)*

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provision - G: Non-nuclear inducements

4. Economies of scale (B)	*4. Issue of returning Pu and/or radioactive waste to customer country (A, B)*
5. Fewer bigger reprocessing centres mean fewer environmental impacts, safety risks and health risks (A, B, E)	*5. Breakout scenario and retention of fissile materials (A, C, D)*
	6. Possible increase in transportation requirements (A)

199. The comments made previously for this type – in the case of enrichment – are also valid here.

5.4 - Spent fuel repositories (final disposal)

200. Once nuclear fuel has been used in a nuclear power plant to produce electricity, the fuel has been "spent" and awaits further treatment, either towards a reprocessing facility to recover from the wastes the uranium and plutonium that it contains, or in an intermediate storage building or in a "final repository" for a terminal solution. Most of the spent fuel around the world is now kept in the nuclear plants themselves, where it comes from. Depending on the route selected, a final repository may thus receive unprocessed fuel assemblies (spent fuel), or plain wastes, or both. Are such special facilities candidates for multilateral approaches? Besides the expected economic benefits of multinational repositories, there is a reason to look at them in terms of non-proliferation in the case of spent fuel, because the potential risk associated with the contained plutonium, plutonium whose accessibility increases with time due to the radiological decay of the associated fission products.

Technologies

201. A repository is an underground installation for the disposal of nuclear material, such as spent fuel, usually located several hundred metres below ground level in a stable geological formation that ensures long term isolation of radionuclides from the biosphere. In the operating phase, the repository will include a reception area, which may be above or below ground, as well as container handling and emplacement areas underground. After the final closure, the backfilling of all emplacement areas in the repository will have been completed and all surface activities ceased.

202. The technology of spent fuel disposal has been well developed over the years, notably in Scandinavia, where the fuel assemblies are embedded in a solid container (such as copper) before burial. There is thus no concern that multinational final disposal would be less safe or less environmentally acceptable than national solutions.

Historical background

203. Although international centres concentrating all nuclear fuel cycle activities in a limited number of countries were proposed very early in the development of nuclear power, the first study on "multinational repositories" for radioactive waste and spent fuel was performed by OECD-NEA in 1987. No such repository has ever been realised, with the possible "exception" of the NEA-led disposal in deep-oceanic sites of low-level wastes in the seventies. Nevertheless, nuclear materials have been transferred to other countries for disposal and precedents for international disposal exist in the related area of toxic chemical wastes, with the agreed mutual exchange of waste across boundaries for optimal recycling and final disposal.

204. The transboundary movements of such waste are regulated by the Basle Convention. The "*Basle Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*" entered into force in 1992. The Convention is the response of 162 countries to the problems caused by the annual world-wide production of 400 million tonnes of wastes, which are hazardous to people or the environment because they are toxic, poisonous, explosive, corrosive, flammable, eco-toxic, or infectious. The common goal is the reduction of special wastes through avoidance and recycling, and the environmentally tolerable and largely clustered disposal of wastes. This global environmental treaty strictly regulates the transboundary movements of hazardous wastes and places obligations on its Parties to ensure that such wastes are managed and disposed of in an environmentally sound manner. In order to achieve these principles, the Convention controls, to some extent, the transboundary movement of hazardous wastes, monitors

it, provides assistance for the environmentally sound management of hazardous wastes, promotes cooperation between Parties in this field, and develops technical guidelines for the management of hazardous wastes.

205. Article Eleven of the Basle Convention is entitled "**Bilateral, Multilateral and Regional Agreements**": *1. ... Parties may enter into bilateral, multilateral, or regional agreements or arrangements regarding transboundary movement of hazardous wastes or other wastes with Parties or non-Parties, provided that such agreements or arrangements do not derogate from the environmentally sound management of hazardous wastes and other wastes as required by this Convention..."*

206. In fact, many countries continue to depend on facilities beyond their own border for recycling certain special wastes (e.g. for metal wastes) and for the disposal of various types of toxic wastes. The export is only permitted if national and international regulations are kept and the environmentally tolerable treatment of the wastes can be assured.

207. The OECD countries and the European Union have gone beyond the obligations of the Convention by agreeing to ban export to non-OECD countries of hazardous wastes intended for final disposal. This commitment has helped in securing the support of non-governmental organisations, which were keen to stop the uncontrolled dumping of wastes on the shores of developing countries.

208. Under the Convention, transboundary movements are an accepted practice: 5-10% of the total waste is involved, with about 50% going to final disposal. The five largest exporters are Germany, Canada, the Netherlands, Switzerland and the USA. The last of these has signed, but not ratified the Convention. All these States, and others, import waste as well. This results in a better optimisation of final disposal of various kinds of toxic wastes.

209. The Convention on toxic wastes and its implementation is indeed a model for multilateral arrangements, a model that brings maximum benefits in terms of economics and environmental protection.

210. By contrast, the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" of 1997 is more cautious on multilateral exchanges, but is still encouraging on this matter through a clause in the Preamble: *"xi) Convinced that radioactive waste should, as far as is compatible with the safety of the management of such material, be disposed of in the State in which it was generated, whilst recognising that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects;"*

Current status

211. No shared multinational repository exists currently. However, a number of initiatives pursue the idea[25]:

a) The Arius Association brings together organisations from various countries (Belgium, Bulgaria, Hungary, Italy, Netherlands, Slovenia and Latvia), whose main objective is to explore ways of making provision for shared storage and disposal facilities for smaller users, who may not wish to - or may not have the resources to - develop facilities of their

[25] MCCOMBIE, C. et al; " Nuclear Fuel Cycle Centres - an Old and New Idea", World Nuclear Association, Annual Symposium 2004.

own. The SAPIERR project is a regional feasibility study supported by the European Commission; SAPIERR stands for "*Support Action: Pilot Initiative on European Regional Repositories*" and is a project within the sixth EC Framework Programme. The Ljubljana Initiative is a group of seven contiguous countries in Central Europe, Austria, Bulgaria, Croatia, the Czech Republic, Hungary, Slovakia and Slovenia. The participants want to assess the potential safety, security and economic advantages of shared solutions.

b) The Russian Federation has become increasingly serious about spent fuel import and is the only country publicly supporting this at government level. The government is preparing international arrangements for the import and storage of spent fuel. For the time being, the offer does not include the final disposal of spent fuel. In July 2005, the Russian Federation will be holding an international conference in Moscow for Multilateral Technical and Organisational Approaches to the Nuclear Fuel Cycle aimed at strengthening the nuclear non-proliferation regime.

c) The IAEA has continued to work on the topic with dedicated working groups, and has published a substantial document on the issue in October 2004 (TECDOC-1413; "*Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation*")

212. At the national level, several countries have moved towards the realisation of final repositories for high level waste, notably Finland, Sweden and the USA. In many countries, there are both political sensitivities and legal, including in some cases constitutional, barriers associated with the potential import of waste, a concern which would complicate this aspect of MNAs.

213. Yet, the experiences gained in regard to toxic wastes in the OECD/EU countries are reassuring. They address several of the concerns that some within and without the nuclear community have raised against shared nuclear repositories. Specifically, no State party to the Basle Convention is obliged to accept wastes from others. All exchanges, even for disposal, are voluntary and based on freely-entered-into bi- or multilateral agreements subject to international oversight. As noted previously, there is even a joint commitment of OECD/EU countries to keep all wastes for themselves.

Economics

214. Multinational repositories offer numerous economic benefits for both the host and the partner countries with small nuclear programmes. Sharing a facility with a few partners can significantly reduce a host country's expenditures. Of course, since the host country will bear the burden of permanently housing the repository, (and since some partners may be saving the costs of establishing their own centralised facility), the host country must negotiate an equitable contribution from its partners towards the total development costs of the project. Partner countries should agree to pay the host country not only some or all of the costs of development, but also a fee on the operation of the site. Therefore, multinational agreement will spread the full burden of development costs among several partners, thereby significantly reducing these costs for individual members. In most countries, a fee is levied on each nuclear kilowatt-hours (kWh) produced, prior to construction of disposal facilities.

215. The economics of spent fuel disposal are very difficult to understand. Many figures reflect the decade-long delay in coming up with technical and political solutions. The following cost estimates are based on calculations made by the Finnish waste management company Posiva as a basis for financial liability for spent fuel management in Finland. They are based on a favourable

socio-economic framework and with a significant amount of R&D already done at home or elsewhere:

Site and facility specific research, development and design costs: *around 200 M€*

Fixed costs: (construction of the encapsulation facility and the disposal facility excluding disposal tunnels, decommissioning and closure of the facilities) *about 250 M€*

Variable costs (waste canisters, operation of the encapsulation facility, construction of disposal tunnels, operation of the disposal facility), per tonne of uranium (tU) *about 0.24 M€/tU*

216. If site and facility-specific R&D is included into fixed costs, the following cost formula gives a first-order approximation:

Cost = 450 M€ + 0.24 M€ x spent fuel amount

217. The unit costs for various amounts of spent fuel to be disposed of would be as follows:

Amount of spent fuel (tU)	*10002000400060008000*
Unit costs (M€/tU)	*0.69 0.47 0.35 0.32 0.30*

218. When the total spent fuel amounts approaches 10000 tU, additional investments are probably needed, e.g. parallel encapsulation process units, new access routes to and in the repository, thus the unit cost will probably not be lower than 0.30 M€/tU. For comparison, the volume of fuel to be disposed of amounts to about 2500 tU in Finland, 10000 in Sweden and 100000 in the United States.

219. As noted, the above cost figures reflect favourable conditions and thus somewhat optimistic scenarios. In countries such as Germany, Sweden, Switzerland and the USA, the real costs are much higher due to technical difficulties, political controversies, and programmatic delays extending over several decades.

220. Advance cash payments, or cost sharing, over a long time period will be needed, from site selection activities to site construction, operation and post-closure monitoring and maintenance. Long-lasting financial arrangements are thus unavoidable, and these can be made in several forms among which could be guarantees as to the amount and time at which certain waste streams would be available, or agreements as to the fees that could be charged for such waste. These could be ultimately paid by the waste generators who would use the multinational repository.

221. Liability is closely related to cost. Several factors can lead to cost increases beyond the estimates, and these have to be properly identified and evaluated (e.g. usual contingencies, changing safety requirements, actual experience, advanced state-of-the-art, unforeseen events, etc.) To deal with liability, two typical examples can be envisaged. In the first case, at the time of receiving the waste, the host country may take all responsibilities or liabilities for any possible future remediation. In the second, the host country and partner countries may conclude an agreement by which the partners accept a partly open-ended situation and assume liability for improbable but not impossible future events which might require remediation. Choosing between the two approaches (or any intermediary approach) may depend on institutional factors, half-lives of the predominant radionuclides, practical experience from other international joint ventures, etc.

Assurance of services

222. "Assurance of services", in this context, refers to "assurance of final disposal" of one's fuel. A State (for political reasons) and its nuclear plant operators (for operational reasons) must be assured that the spent fuel (or the high level wastes coming back from reprocessing) will indeed be disposed of nationally or internationally, in due time. For a multinational repository or a take-back agreement, this implies a solid, long-lasting relationship between the parties and an efficient legal framework in the disposal country.

223. The partners involved would need to agree about the timing of the transfer of waste ownership to the recipient country and on the scope of such property transfer. Transfer could occur at the time when the waste is inspected in the partner's conditioning facilities before transportation, or when the conditioned wastes enter the host country at the national border, or upon receipt in the repository of the host country. It is conceivable that the transfer could occur at a later stage after which any new and additional costs are extremely unlikely to occur.

224. Transfer of ownership of spent fuel may be complicated, since spent fuel can also be considered as a resource rather than a waste. If spent fuel is held for interim 7cooling period of 30 to 50 years, the date of ownership transfer can be delayed.

Legal and institutional

225. Current and future inventories of all types of waste materials for disposal must be established before serious consideration can be given to establishing a multinational repository. Also, there should be an agreement between the host country and its partners as to waste acceptance criteria, locations of facilities for waste conditioning and interim storage (i.e. at each partner country or at centralised facilities installed on the site of the multinational repository), and quality assurance and control of waste packages to be disposed of. The legal and institutional problems to be resolved are not trivial.

226. States with few nuclear plants would be the most interested in making use of international instruments. Multilateral disposal arrangements imply a willingness to open borders. For States with legislation restricting the export and import of radioactive waste, such legislation will have to be amended, if they wish to join a multinational repository project. The case of Switzerland is of interest here: the new nuclear law that entered into force in February 2005 leaves the door open to both export and import of spent fuel and nuclear waste for final disposal, albeit *both* subject to a right of return to the sender "in case of necessity".

227. All considerations about cost sharing, liability, safety regulations, etc. are closely linked to the institutional character of the project, which involves national and multinational relations among regulatory and licensing bodies, as well as with contractual partners. Management of shared repositories could be entrusted to commercial firms, to the host State, or to a consortium of States. At any rate, there should be a clear international framework with agreed guidelines and rules to satisfy the requirements of the partners sending in fuel and IAEA safety standards.

228. A repository is a long-term management project. It has a lead time of 20 years or more, an operational period of several decades and a post-closure surveillance and monitoring period that may extend over centuries. Thus it should be run under an international convention or agreement. This underlines once again the importance of continuity, not only from a political and contractual perspective, but also from a technical and cost sharing point of view. Given the impossibility of predicting how these aspects will evolve over very long time periods, flexibility will be essential.

229. As far as safety regulations for an international repository are concerned, the countries involved should arrive at a common understanding on the licensing and control mechanisms to be applied. There are also legal international instruments that could be used as existing international conventions, e.g. the "*Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*", under which they could regulate their partnership.

Non-proliferation and security

230. Today more than ever, the security of nuclear materials must remain a high priority at all levels – whether national, regional, or international – at the front end and back end of the fuel cycle. The plutonium contained in spent fuel is indeed a material of interest for the making of nuclear explosive devices, albeit to a different degree, depending on the time spent by the fuel in a reactor.

231. The safeguarding of nuclear materials must be undertaken through the entire nuclear fuel cycle, up to the stage where the materials can be considered to be *practically irrecoverable* (e.g. currently, less than 2.5 kilograms of plutonium per cubic metre of vitrified high level waste). Otherwise, in particular for spent fuel, where the content is higher than the threshold noted above, safeguards must be continued even after the closure of a repository.

232. Over the last decade, the IAEA's Department of Safeguards has worked towards defining a safeguards policy on nuclear waste and spent fuel. Several Advisory Group and Consultants meetings were held, and an ambitious "Programme for Development of Safeguards for the Final Disposal of Spent Fuel in Geologic Repositories (SAGOR)" was started in 1994 and finalised in 1998.

233. With respect to nuclear waste, according to SAGOR, the criteria for making determinations of 'practicably irrecoverable' should include waste material type, nuclear material composition, chemical and physical form, and waste quality (e.g. the presence or absence of fission products). The total quantity, facility specific technical parameters and the intended method of eventual disposal should also be considered. The main concern from the waste management standpoint is that any intended safeguards measures should not impair the safety of the waste management system. Another consideration is related to the additional costs associated with the need to implement safeguards measures. The Advisory Groups and Consultants concluded that spent fuel does not qualify as being practically irrecoverable at any point prior to, or following, placement in a geological formation commonly described as a 'permanent repository', and that safeguards on spent fuel should not be terminated.

234. As far as spent fuel is concerned, various safeguards methods and techniques have been proposed for application at a spent fuel conditioning facility. None of the proposed techniques are likely to cause significant problems from the safety point of view. No destructive verification techniques are foreseen.

235. For closed geological repositories, the safeguards approach must provide a credible assurance that an undeclared breaching of the integrity of a repository will be detected. The repository should be safeguarded by a non-intrusive surveillance mechanism that would allow the repository site to be checked periodically, e.g. unannounced inspections, possibly with geophysical equipment, satellite or aerial monitoring and seismic monitoring with remote data transmission.

236. According to the IAEA Department of Safeguards, safeguards approaches for the final disposal of spent fuel repositories will be available in sufficient time to be included in the design for future MNA repositories.

Options for final repositories of spent fuel

237. Defining options for potential multilateral approaches for the back end of the fuel cycle is relatively complex, since there is a dotted line between storage and disposal. As a first priority, the owners of nuclear plants want to off-load spent fuel as early as possible in order not to congest their own spent fuel storage ponds. "Assurance of Service", in this context, refers to "getting rid of" the spent fuel. Further down the line, for countries with inadequate domestic energy resources (such as France, India, Japan, Pakistan and Switzerland), keeping a hand on spent fuel and reprocessed plutonium is important, since this material is seen as an energy resource to be recovered immediately or possibly later after many years of interim storage. For other States not interested in plutonium recovery, storage is only an intermediate step on the way to disposal in geological repositories. There is thus some ambiguity for storage with regard to its duration, its nature and whether it is a precursor of reprocessing or of disposal. This ambiguity even extends to disposal in geological repositories, as indicated by technical specialists references to the oxymoron: "reversible and retrievable final disposal".

238. Thus, depending on the State, time period and conditions of the uranium market (which affects the commercial value of plutonium), assurance of service for spent fuel may take different forms: a) availability of interim storage, b) availability of reprocessing services in the medium or long term and c) outlook for final repositories whether retrievable or not. The first two forms are treated in separate sections of this report. In the present section, the prime interest is on multilateral, shared final repositories for spent fuel, and on the assurance of services for nuclear power plants operators to dispose of the spent fuel produced in their facilities. Three types of multilateral approaches deserve consideration.

***Type I*: Assurances of services not involving ownership of facilities**

a. Suppliers provide additional assurances of supply

239. This option corresponds more or less to the former practice of the Soviet Union under which fresh fuel was supplied to the owners-operators of Soviet-designed plants with a full commitment to take back the spent fuel that was thereby returning to Soviet ownership, with an indefinite status for the fuel itself. The Russian Federation is ready to honour this commitment insofar as reprocessing and storage are concerned. There is now a similar arrangement being negotiated between Iran and the Russian Federation. Incidentally, nothing would prevent other nuclear fuel companies to offer on a commercial basis "fuel leasing-fuel take back" arrangements. In addition to fuel take-back, one could also envisage just *take*, i.e. the host country for the repository does not have be the one that supplied the original fuel. At present, while fuel leasing is relatively straightforward, fuel take-back, while more controversial, is more relevant from a non-proliferation standpoint.

Pros*	Cons
1. No remaining security risk in client State (A)	*1. Concern that recipient State could acquire valuable weapon-quality plutonium (A)*
2. Ease of implementation, few participants (B)	*2. Assurance of service depends on one partner (B)*
3. Secured, final solution to waste disposal (B)	*3. Issues surrounding long-term ownership of Pu (B)*
	4. Legal barriers in many States against accepting foreign spent fuel (B)

* A: Non-proliferation - B: Assurance of supply - C: Siting – D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions - G: Non-nuclear inducements

240. A form of partial "fuel leasing-fuel take back" is also conceivable, under which the donor State would accept to take back an amount of vitrified (or otherwise appropriately conditioned) high level wastes corresponding to the quantity and toxicity of the fission products contained in the spent fuel.

b. International consortia of governments

241. This model would be a collective "**fuel leasing-fuel take back**" arrangement involving several nuclear fuel companies together with their governments (fuel take-back would have a political dimension). They would hold the material received, take ownership, store it temporarily or definitively, or even reprocess it. The contractual arrangements would specify, on a case-by-case basis, whether the lessee would be entitled to purchase back the equivalent amount of **mixed-oxide fuel** that it had transferred previously in the form of spent fuel, even when such arrangements would primarily meant to cover final disposal.

242. Partial "fuel leasing-fuel take back" could also work here.

Pros	**Cons**
1. No security risk in lessee State after return of fuel (A)	*1. More difficult implementation, involving several participants (A, B)*
2. Rapid to implement after political decision (B)	*2. Political will of several recipients needed (B)*
	3. Changing political conditions over long term could alter commitments (E)
	4. Existing property rights must be taken into account (B, E)
	5. Legal barriers in many States against accepting foreign spent fuel (B)
	6. Issues surrounding long-term ownership of Pu (B)

c. IAEA-related arrangements

243. The IAEA has been entrusted with the NPT-related obligations to safeguards and thereby to keep track of the spent fuel in final repositories. There is unlikely to be any additional role for the Agency in any bilateral or multilateral arrangements. While the IAEA could possibly be in a position to "give" (for example managing a fresh fuel bank), its Members-States would probably be unwilling to allow it to "receive" spent fuel in specific final disposal facilities, with all the costs and risks that this would imply, except maybe in an oversight function thereby providing better acceptance.

***Type II*: Conversion of existing national facilities to multinational ones**

244. In this case, the host country would add imported wastes from partner countries to its national inventory and disposal scope. It could do so after its national facility is seen to be operating safely. The anticipated income would allow the construction of modern repositories with good security and environmental characteristics. Furthermore, one could even envisage regional arrangements involving not only spent fuel and radioactive wastes, but also chemical toxic wastes.

245. Many political and public acceptance issues will arise in connection with the import of nuclear materials to an existing repository. Successful implementation of disposal programmes on the national level, good transparency of the international dimension of the project – broad

adherence to international instruments such as the NPT and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management – could significantly contribute to the acceptance of such an international repository project. The countries sending their nuclear materials will certainly require guarantees of good safety and environmental management through some kind of international oversight, i.e. through the IAEA.

Pros*	Cons
1 Reduce proliferation risks (A)	*1. Political and public acceptance (B)*
2. Energy resource (Pu) secured and available (B)	*2. Uncertainty about consent rights, as to retrievability and transfer (B)*
3. Best economics for all partners(B)	*3. Assurance of service depends on only one partner (B)*
4. Existing secure and safe facility in host country (A)	*4. Possibility of retrieval (A)*
	5. Changing political conditions over long term could alter commitments (B, E)
	6. Existing property rights must be taken into account (B, E)
	7. Legal barriers in many States against accepting foreign spent fuel (B)
	8. Increased transportation requirements (A)

***Type III:* Construction of new joint facilities**

246. The launching of a project of multinational repository would begin with solid technical evaluations of waste characterisation, conditioning and transportation. Analyses would need to be carried out related to the inventories, cost/benefit, safety and legal issues. The identification of suitable repository sites is of paramount importance, since the specific safety, environmental and political aspects associated with the proposed sites will effectively determine the fate of such an international project. No effort should be spared to establish a strong technical and scientific basis for choosing the most suitable location in terms of safety and environmental impact. Among the factors that will play a role in choosing the host State are: political willingness; geologic stability; good regulatory infrastructure; political stability; non-proliferation credentials; and the agreement of consent rights and trans-shipment States.

247. Public acceptance is already of crucial importance for setting up national repositories; it will even be of greater importance for multinational repository projects with nuclear waste and spent fuel coming from several countries. Slogans such as "Dumping ground of the world...", "Not in my backyard..." would most likely come up as soon as an international project of this kind was mentioned. High safety standards and cost transparency are thus essential for obtaining public acceptance for a multinational repository project.

248. To overcome the so-called NIMBY syndrome on an international scale, there should be more than one international repository, perhaps even more than one per continent. Host countries would certainly prefer not to be the sole site. Several regional repositories would minimise transport, and customer countries would have some degree of flexibility. One could imagine, worldwide, two North American repositories, one in South America, two in Western/Central Europe, one each in Russia, in Africa, in South Asia, in China and in South-East Asia.

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions - G: Non-nuclear inducements

249. The burden would lie first of all on the shoulders of the host country and its government. There are several steps that the host government, the participating countries and the international community could take to help gain the required public acceptance:

a) The number and nature of the participating countries would play a role in public acceptance in the host country: not too many, not too few. Strong political support of the partner countries is an absolute prerequisite for achieving public acceptance;

b) While the participation of solid industrial partners would be necessary to ensure the technical viability and economic soundness, the involvement of governments and other public entities is needed to strengthen public acceptance with an assurance of long-term continuity;

c) For spent fuel disposal, the non-proliferation dimension of the repository can be emphasised in the justification and presentation of an international repository. The host country would thereby provide a safe central shelter for the plutonium contained in the spent fuel, rather than leaving it scattered in numerous facilities around the region;

d) For "retrievable spent fuel disposal", the host country would thereby provide temporary storage for a valuable resource - the plutonium - which is a large potential source of energy for future use, should the participants need it in the future. Depending on the ownership agreement between the participating countries, the host country could thus acquire a potentially exportable commodity.

Pros*	**Cons**
1. Economies of scale (B)	*1. Difficult implementation, with several participants (A, B, E)*
2. Solution for countries with unsuited geology (B)	*2. Difficulty of national public acceptance (B, C)*
3. Combining rather than duplicating efforts (A, B, E)	*3. Increased transportation requirements (A, B)*
4. Solution for countries with political acceptance problems (B)	*4. "Not in my backyard" on international scale (B)*
5. Better security in one location (A)	*5. Changing political conditions over long term could alter commitments (B, E)*
6. Possibility of retrieval for future energy needs (B)	*6. Proliferation risks with the possibility of retrieval (A)*
7. Energy resource (Pu) secured and available (B)	*7. Legal barriers in many States against accepting foreign spent fuel (B)*

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions - G: Non-nuclear inducements

5.5 - Spent fuel storage (intermediate)

250. The following section discusses spent fuel storage and whether this part of the fuel cycle is a candidate for multilateral arrangements. Without making specific reference to the front end, most of the findings can be applied there mutatis mutandis.

Technologies

251. At the back end of the fuel cycle, spent fuel containing plutonium is frequently stored for long periods of time while awaiting reprocessing or final disposal. At the front end, prior to use in nuclear power plants, fresh fuel is stored on site, be it as plain uranium oxide fuel (UO_2) or as mixed oxide fuel (UO_2 and PuO_2); such fuels represent limited proliferation risks in small quantities inside nuclear plants, more when in longer interim storage as fresh fuel buffer stocks elsewhere.

252. The technology of nuclear material storage has been fully developed over the last decades, and this experience will be directly applicable to multinational arrangements. The relevant technical issues are: safety; physical protection; safeguards; fuel acceptance criteria; long-term stability; siting; storage technology (wet or dry); licensing; facility operation; transport; and decommissioning.

Historical background

253. The concept of an extra-national trusteeship of special nuclear materials is enshrined in the Statute of the IAEA. Although evaluated at length by an international Expert Group around 1980 (in parallel with the International Plutonium Storage evaluation referred to in the historical review), the concept of "International Spent Fuel Storage" never became reality. A study of multinational storage facilities for spent fuel was initiated by the IAEA in 1997.

Current status

254. Today about 165 000 tonnes heavy metal equivalent (tHM) of irradiated fuel (spent fuel) from nuclear power reactors are stored world-wide. By the year 2015, the mass of stored spent fuel will rise to about 280 000 tHM. More than 62 000 fuel assemblies from research reactors also are stored worldwide.

255. No shared multinational storage facilities exist currently. Storage of spent fuel will cover longer periods of time than originally expected, and storage up to 100 years is being discussed now.

256. The IAEA continues to work on the concept for regional spent fuel storage. The objective and scope is similar to that on disposal repositories. A substantial Technical Document is in preparation ("*Technical, economical and institutional aspects of regional spent fuel storage facilities*"). IAEA staff have presented to the MNA Expert Group preliminary findings of the study, which will be a very valuable contribution for the assessment of such multinational arrangements.

257. The adjacent figure – from the IAEA Technical Document - shows the possible paths of nuclear materials around a regional store, and the interfaces with disposal and reprocessing.

258. Most countries with power reactors are developing their own national strategy for spent fuel management, including interim storage. However, several countries with small nuclear power programmes, or only research reactors, face the issues of extended interim storage of their spent nuclear fuel. The high cost for interim storage facilities for small amounts of spent fuel accumulated in such countries is obviously not reasonable and therefore, from an economic point of view, access to a regional interim storage facility provided by a third country for their fuel would be an interesting solution.

259. The benefits and challenges of multinational storage are quite comparable to those of multinational disposal. Long term conditions and legal issues applicable to final repositories may not apply in this case or may be of a lesser impact. Greater benefits in the case of storage may favourably impact the acceptability of regional storage projects, i.e. hundreds of storage facilities are in operation worldwide, the time scale for storage is shorter and storage is by definition fully reversible. Hence, political and public acceptance is more likely.

Economics

260. In the future, there may be regional and national bottlenecks, with shortages anticipated in several countries. The costs and the obstacles associated with fuel transportation would preclude a smooth matching of demand and capacity on a worldwide basis.

261. Multinational stores could offer significant economic benefits to both the host and the partner States. Sharing a facility with a few partners can significantly reduce costs in the case of wet storage, less for dry storage, which is more modular in nature.

262. Potential service providers include:

a) States willing to take advantage of a business opportunity or for other interests (i.e. non-proliferation);
b) States with advanced nuclear waste management programmes, that are willing to accept additional spent fuel for storage;
c) States which have existing reprocessing facilities with available or readily expandable reserve storage capacity; and
d) States with small or extensive nuclear programmes that have favourable sites that could be developed for use by other countries.

263. Potential customers include:

a) States with small nuclear programmes that cannot realistically develop economically effective comprehensive back end facilities; and
b) States with large or small nuclear programmes that may see an attractive economic or political advantage in using a regional storage solution.

264. Cost sharing will extend over long time. Long-lasting financial arrangements are thus unavoidable, and these can be made in several forms among which could be guarantees as to the storage duration.

Assurance of services

265. "Assurance of service", in this context, refers to the "assured storage" of one's fuel. For operational reasons, nuclear plant operators must be assured that the spent fuel discharged from

their reactors will have somewhere to go, once the on-site stores have been filled up. Intermediate storage – pending disposal to reprocessing or to a repository – must therefore be prepared either nationally or internationally.

Legal and institutional

266. A regional approach to the storage of spent fuel would require the involvement of a variety of relevant institutions, including national, multilateral, supranational (i.e. EU) and international entities. On an international level, institutions like IAEA, OECD/NEA, EURATOM, etc. could be involved. On a national level, governmental and regulatory bodies, local authorities, oversight bodies as well as spent fuel producers and facility operators will take part in the process.

267. Multilateral storage arrangements imply a willingness to work together. Since storage may extend over decades, the facility must be run under an international convention or agreement. The political stability of the host and the partners is again a vital element. This underlines once again the importance of the continuity factor, not only from a political and contractual perspective, but also from a technical and cost sharing point of view. Management of a shared store could be entrusted either to commercial firms, to the host State, to a consortium of States. At any rate, there should be a clear international framework, with agreed guidelines and rules.

268. Another challenging issue for multinational facilities has to do with the ownership of spent fuel and transfer of title. Because such projects are long-term and the final destination of spent fuel may not have been decided, three options regarding the ownership of spent fuel stored in such a facility need to be considered:

a) Ownership of fuel remains with the providing customer; after the storage period expires, the fuel (or reprocessing products if appropriate) is returned to the owner;

b) Transfer of ownership to the host country is delayed and can take place at some later time, depending on contractual arrangements; and

c) Ownership of fuel is immediately transferred to the host country; no return of fuel (or reprocessing products, if appropriate) is foreseen.

269. In the first option, the agreement to take back the spent fuel in a distant future may be a risk for both sides; on the customer's side, uncertain government policies may prevent the delivery and the payments for spent fuel, while on the host's side the delay in accepting fuel may cause negative economic and political reactions and thereby jeopardise the whole project. Because of the need for an agreement to receive spent fuel, the contract between the host and the customer States requires strong commitments on both sides. An international assurance that the agreements will be respected may be required, with a possible IAEA involvement.

270. The second option includes the possibility of the transfer of title at some future time, depending on possibilities in both the host and the customer countries. The risks associated with this option are similar as for the first one and some international assurance may also be required.

271. The third option avoids the problems of fuel take-back. This option may be the most attractive to the customers' countries. The host country takes the responsibility for storage and the final disposition of the spent fuel. However, some questions may arise when disposal routes are not yet available (after storage), as to the potential commercial value of the spent fuel as an "energy resource". These issues should be negotiated very carefully between the parties.

272. Liabilities are associated with the obligation of the spent fuel owner to ensure that the spent fuel is properly managed and finally disposed of in a safe and secure manner. Several factors can lead to cost increases and these have to be properly identified and evaluated, i.e. usual contingencies; changing safety requirements; actual experience; advanced state-of-the-art; unforeseen events, etc. These liabilities are an inherent cost of managing normal operations of a multinational storage facility. In addition, abnormal operations must be addressed through contracts in the context of national laws and applicable international treaties. Future liabilities of the host country of regional spent fuel storage facility are strongly related to the issue of spent fuel ownership.

Non-proliferation and security

273. The safeguarding of special nuclear materials is a well-established practice with clear criteria. Spent fuel stored in a multinational store in an NNWS, whether in a multinational or national store, will be subject to IAEA safeguards. Customer-States may also require that safeguards be applied in a multinational store located in an NWS.

274. If one focuses on security, it is of interest to note that storage facilities located above ground are more vulnerable to external risks than underground disposal facilities.

Options for multilateral spent fuel storage

275. A complex situation prevails at the back end of the fuel cycle where a dotted line runs between storage and disposal, as already noted at the same location in the chapter on repositories. There is thus an ambiguity for storage as well, regarding its duration, its nature and whether it is a precursor of reprocessing or of disposal.

276. Depending on the State, time period and reprocessing market (whether commercially attractive or not), assurance of service for spent fuel storage may take different forms. Three types of multilateral approaches are also under consideration here:

Type I: Assurances of services not involving ownership of facilities

a. Suppliers provide additional assurances of supply

277. There is a comparison with the front end of the fuel when fresh fuel is stored by the fuel supplier prior to shipment to their clients: the owners-operators of power plants. Such fresh fuel buffer can be expanded in volume to provide a buffer function. This arrangement could be mirrored at the back end; a commercial entity would commit to take-back and store the spent fuel until its fate is decided between reprocessing and disposal. This could also be seen as a buffer associated with the recyclable plutonium. The Russian Federation has committed to receive spent fuel from Russian-supplied reactors for storage. An extension of this proposal to non-Russian-supplied fuel is under consideration.

Pros*	Cons
1. Less security risk in client State (A, B)	*1. Concern that receiving State could take hold of valuable weapon-quality plutonium (A)*
2. Ease of implementation, few participants (B)	*2. Assurance depends upon one partner only (B)*
	3. Concern that fuel would not be taken back (B)

b. International consortium of governments

278. This model - a form of spent fuel bank - would involve additional suppliers and possibly their governments. Suppliers would hold the material received without keeping or taking ownership, and store it temporarily for an indefinite period of time, thereby creating a collective strategic fuel reserve, with some kind of government guarantees.

Pros	Cons
1. Reduced security risk in client State (A, B)	*1. Implementation with several participants (E)*
2. Assurance of service relies on several partners (B)	*2. Multinational, therefore political decisions needed (A, B, E)*
	3. Concern that the fuel would not be taken back (A, B)
	4. Existing property rights must be taken into account (B, E)

c. IAEA-related arrangements

279. The attempts to internationalise nuclear material management/storage goes back to Article XII A.5 of the IAEA Statute. From this paragraph came the concept of "International Plutonium Storage" that provided for the management of special fissionable materials by the Agency:

"...to require deposit with the Agency of any excess of any special fissionable materials recovered or produced as a by-product over what is needed for the above-stated uses in order to prevent stock-piling of these materials, provided that thereafter at the request of the member or members concerned special fissionable material so deposited with the Agency shall be returned promptly to the member or members concerned for use under the same provisions as stated above".

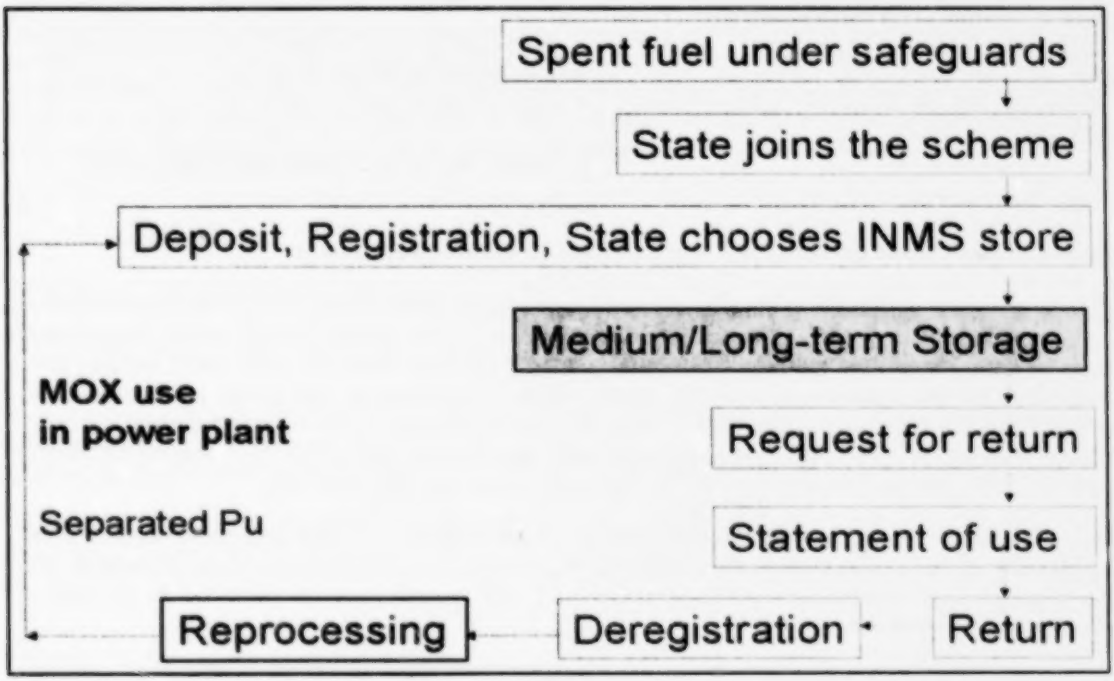
280. Although evaluated at length by two separate international expert groups between 1978 and 1982, the idea never materialised, for both separated plutonium and for spent fuel. States were not willing to forgo their control of valuable nuclear materials. Furthermore, the original non-proliferation concerns had by that time lost their momentum in comparison to 1957 as a consequence of the advance of safeguards under the NPT since 1970.

281. This idea could be revived under the name of "International Nuclear Materials Storage (INMS)". In the case of separated plutonium, the concept would primarily apply to the mixed-oxide fuel (MOX) that is returned and stored prior to use in nuclear power plants. In contrast to the reluctance of renouncing national sovereignty over *separated* plutonium, the international storage of *unseparated* plutonium (that is, of spent fuel) could generate more interest. Today, there is the possibility of greater political flexibility in the case of spent fuel, a resource that is less immediately

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions - G: Non-nuclear inducements

valuable, more difficult to store and also less sensitive than separated plutonium in terms of proliferation.

282. On the basis of a model proposed in 1982, the flow of material in and out of IAEA trusteeship is illustrated in the adjacent diagram.



283. The following arrangements would apply to a participating country, whether an NNWS or not:

a) Coverage: all spent fuel and separated Pu therefrom - from peaceful use;
b) Return: upon request, authorisation to be granted for reprocessing and then peaceful uses, with all materials under safeguards and with no stockpiling;
c) Use verification: materials flows to be provided; to be verified (beyond safeguards requirements); and
d) Deregistration from the INMS: When safeguards status is modified, from INMS to owner's facilities.

284. Given the large and growing stockpiles of excess plutonium, some have advocated that the time has come for countries to place such material under the international custody of the IAEA pending subsequent peaceful use or disposition[26]. Placing the fuel under IAEA custody could facilitate the use of plutonium-using fuel cycles, help achieve non-proliferation objectives, avoid discrimination among States and interference with national energy programmes. Separated

[26] BENGELSDORF, H.D., MCGOLDRICK, F., "International Custody of Excess Plutonium", Bulletin of the Atomic Scientists, March/April 2002.

plutonium and spent fuel would be kept decentralised in a few locations, an arrangement that would minimise fuel transport.

Pros*	Cons
1. Potential economic advantage (B)	*1. Lack of political will to involve the IAEA (A,B, E)*
2. Good security and non-proliferation framework, under IAEA trusteeship (A)	*2. Complex legal and institutional setup (B, E)*
3. Strong assurance of service (take back, Pu return) (B)	*3. Demanding management task for the IAEA with financial implications (B,E)*
4. Reprocessing and disposal options remain possible (B)	*4. Risk of "breakout" remains (A)*
	5. Increased transportation requirements (A)

***Type II*: Conversion of existing national facilities to multinational ones**

285. In this case, the host country adds to its national inventory and storage capacity imported special nuclear materials from partner countries. Again, a similar option already exists (to a limited extent) with the current commercial practice of storing fresh fuel (uranium and mixed oxides) prior to shipment to the owners-operators of power plants. Such fuel buffer could be expanded in volume to provide a strategic-reserve function. One can envisage regional arrangements to create strategic reserves of fresh fuel, and joint buffer storage of spent fuel, prior to decisions regarding additional reprocessing capacity or final disposal capacity on a regional basis.

286. Economic incentives, the existence of minimum national storage programmes and good transparency of the international dimension of the project would significantly contribute to the acceptance of such international storage projects. There would likely be need for some kind of international oversight (i.e. IAEA).

Pros	Cons
1. Secure and safe facility in host country (A, E)	*1. Difficulty of political acceptance in host country (B, E)*
2. Energy resource (Pu) secured (B)	*2. Uncertainty regarding consent rights (B)*
3. Best economics for all partners (B)	*3. Assurance of service depends upon only one partner (B)*
4. Set up: easy and fast (B)	*4. Increased transportation requirements (A)*
	5. Existing property rights must be taken into account (B,,E)

***Type III*: Construction of new joint facilities**

287. A new, shared storage facility can be established in a regional or multinational context. Among the factors that will play a role in choosing the host State are: political willingness; siting; good regulatory infrastructure; political stability; non-proliferation credentials; agreement of consent rights and trans-shipment States.

288. Political will would depend on understanding at the national level the advantages of joint regional buffer stocks. "Stronger together" would reflect a greater perception of assurances of

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions – G: Non-nuclear inducements

supply and would lead to a better public acceptance of nuclear energy. High safety standards, reliable quality assurance, fair and transparent cost sharing would also be essential for obtaining political support for a multinational storage project. While the participation of solid industrial partners would be necessary to ensure the technical viability and economic soundness, the involvement of governments and other public entities is needed to strengthen public acceptance with an assurance of long-term continuity. For spent fuel storage, the non-proliferation advantages of the regional store should also be emphasised. The host country would thereby provide a safe central shelter for the plutonium contained in the fresh and spent fuel, better than leaving it scattered in numerous facilities around the region. For spent fuel storage, it can also be mentioned that the host country would thereby provide temporary storage for a valuable resource - the plutonium - which is a large potential source of energy for future use, should the participants need it later on in 30 or more years. Depending on the ownership agreement between the participating countries, the host country would thus acquire a potentially exportable commodity.

Pros*	Cons
1. Economies of scale (B)	*1. Difficult implementation, with several participants (A, B, E)*
2. Solution for countries with unsuited geology (B)	*2. National public acceptance (B)*
3. Combining rather than duplicating efforts (E)	*3. Increased transportation requirements (A, B)*
4. Solution for countries with political obstacles (B)	*4. "Not in my backyard" on international scale (B)*
5. Better security in one location (A)	*5. Possibility of fissile material retrieval in case of a breakout (A)*
6. Best assurance of service (take back, Pu return) (B)	*6. Possible increase in transportation requirements (A)*

* A: Non-proliferation - B: Assurance of supply - C: Siting - D: Access to technology - E: Multilateral involvement - F: Special safeguards provisions - G: Non-nuclear inducements

5.6 - Overview of options

289. An MNA can be an alternative to national fuel cycle facilities, thereby reducing the number of such facilities. In addition to the possible attractive economic aspects discussed, the intergovernmental agreements envisaged for an MNA could enhance controls on the transfer and use of nuclear materials and restricted technologies, would provide for better physical protection in the facilities and could provide for their optimum siting.

290. To the extent that an MNA offers a greater assurance of adequate control over nuclear materials and facilities than would wholly national facilities, it helps to allay concerns about nuclear proliferation. A joint facility with multinational staff puts all participants under a greater degree of scrutiny from peers and partners, a fact that strengthens non-proliferation and security. This is the fundamental non-proliferation benefit of MNAs. An MNA may also constitute an obstacle to a "breakout" by the host partner. The multinational dimension of an MNA provides no fool-proof assurance against a breakout, but is better, in this regard, than a simple national facility. Naturally, an MNA would be established with the application of full IAEA safeguards.

291. A countervailing factor is the possibility that international cooperation facilitates the diffusion of enrichment and reprocessing expertise, thereby increasing the proliferation risks outlined in Chapter 5.1. From this perspective, for MNAs in general, it would seem that the Urenco model is only applicable when partners have already developed their own individual know-how, while the EURODIF model is better when most have not done so.

Uranium enrichment

292. A healthy market exists for all steps in the front end of the nuclear fuel cycle. In the course of only two years, a nuclear power plant operating in Finland has bought uranium originating from mines in seven different countries. Conversion has been done in three different countries. Enrichment services have been bought from three different companies. For fuel manufacturing, there were three qualified factories, each having different fuel design. Therefore, the legitimate objective of assurances of supply can be fulfilled to a large extent by market mechanisms and possibly improved by some governmental guarantees. However, this assessment may not be valid for all countries that have concerns about assurances of supply. Mechanisms or measures under which suppliers or international consortia of governments or IAEA-related arrangements provide assurances may, in such cases, be appropriate.

293. Further supply arrangements could involve the IAEA under modalities worthwhile exploring. Such IAEA-led models need not be elaborate. Indeed, of the options reviewed, one of the most feasible, least likely to be burdened by financial, legal and technical complications, requiring minimum new institutionalisation and likely to be the easiest to implement, could be that of the IAEA standing ready to be the guarantor of substitute fuel supply arrangements in accordance with agreed criteria in the event that a State had its nuclear fuel supply suspended for other than commercial reasons.

294. Where an MNA would take the form of a joint facility, there are two ready-made precedents, Urenco and EURODIF. The experience of Urenco, with its dual-layer management under the control of its governmental Joint Committee, has shown that the multinational concept can be made to work successfully. Strong oversight of technology and staffing, as well as effective safeguards and proper international division of expertise can reduce the risk of proliferation and even make a unilateral breakout more difficult. EURODIF has a successful multinational record as well, by enriching uranium only in one country and hence restricting all proliferation risks, diversion, clandestine parallel programme, breakout and the spread of technology.

Reprocessing

295. On the basis of present forecasts regarding nuclear energy, and taking into account present capacities to reprocess spent fuel for light water reactors and those under construction, there will be sufficient reprocessing capacity globally for all expected demands for at least two decades. Therefore, objectives of assurances of MOX supply can be fulfilled to a large extent without MNA involving ownerships.

296. The case of reprocessing is similar to enrichment in terms of the associated proliferation risks. However, there are differences between enrichment and reprocessing facilities:

a. A lesser sense of urgency to reprocess spent fuel, which will affect the economic feasibility and timing of constructing new reprocessing plants.

b. Whereas the common practice of returning the reprocessing products to the customer poses a proliferation risk, MNA's will not pose greater risks than the current situation. However, if the reprocessed products will be retained by the host country, the proliferation risks may be higher, depending on the siting of the MNA.

c. Reprocessing technology is more readily available than enrichment technology, and therefore proliferation risks must also be handled at the previous stage of the fuel cycle – safeguarding spent fuel removed from reactor cores. In this respect, it is worth noting that an MNA, which leases nuclear fuel and takes back the spent fuel, avoids most proliferation risks, but requires the fuel vendor to take care of the spent fuel disposition.

297. In the context of reprocessing, the IAEA could possibly exercise the authority granted in its Statute to require deposit of special fissionable materials in excess of on-going national needs. For MNAs involving a new joint facility, design features to enhance safeguardability should be incorporated, such as co-location of facilities including storage, features to improve inventory and accounting of materials, features to improve containment and surveillance; and process selection and storage options to make nuclear materials less vulnerable to diversion. Regional facilities would involve transportation of spent fuel over long distance with its associated obstacles. Therefore, in the views of some States, it is desirable to co-locate nuclear power plants, reprocessing plants, MOX fuel (or mixed metal fuel) fabrication plants and fast reactors to use the MOX fuel. Transportation of spent fuel, if any, should be over short distances.

298. What sets reprocessing apart from other steps of the fuel cycle is the separation of fissile material and its reintegration into fresh fuel. One can make the case that MNAs, because of the greater number and better coordination of suppliers and customers in a single organisation, might achieve a better match between the separation of plutonium and its consumption in the form of fresh fuel.

Spent fuel disposal

299. Many organisations want the disposal of nuclear fuel and waste to be done only domestically. Under the Basle Convention, the OECD has opened the vista by deciding that toxic waste can and must be disposed of within the broader geographical region of the OECD. This eminently reasonable approach does not violate in any way rules of good conduct of an environmental and ethical nature. For nuclear wastes, it would certainly make sense to establish similar regional arrangements in the "OECD/EU region", as well as elsewhere in the world.

300. At present there is no market for spent fuel disposal services, since there is no urgent need - either from a technical or from an economic point of views for having repositories even at the national level in many countries. From a higher perspective, one may observe that nuclear services are offered internationally by a number of players, from uranium ore to reprocessing. Why not also final disposal in order to achieve best security, safety and economics?

301. The final disposal of spent fuel is a candidate for multilateral approaches. It offers major economic benefits and substantial non-proliferation benefits, although it presents legal, political and public acceptance challenges in many countries. The Agency should continue its efforts in that direction by working on all the underlying factors, and by assuming political leadership to encourage such undertakings. For example, the IAEA could launch a "Siteless Pilot Project of Spent Fuel Repository" that would elaborate in detail all related technical, economical, legal and institutional aspects. Beyond the IAEA, in spite of current legal constraints on exports and imports, other regional organisations could become active, such as the OECD, the European Union and the North American Free Trade Agreement.

302. To be successful, the final disposal of spent fuel (and radioactive waste as well) in shared repositories must be looked at as only one element of a broader strategy of parallel options. National solutions will remain a first priority in many countries. This is the only approach for States with major nuclear programmes in operation or in past operation. For others with smaller nuclear programmes, a dual-track approach is needed in which both national and international solutions are pursued. Small countries should keep options open (national, regional, international), be it only to maintain a minimum national technical competence necessary to act in an international context.

303. Besides participating countries, it would seem that the international community at large should also play a role in achieving greater public acceptance for international repositories. The IAEA should put forward proposals for a more active role of the Agency, such as policy statements and resolutions expressing a broad support for international repositories, and possibly for a more active role of the Agency as an umbrella or a sponsor for such projects.

Fuel storage

304. Storage facilities are in operation and are being built in several countries. There is no international market for services in this area except for the readiness of the Russian Federation to receive Russian-supplied fuel, with a possible offer to do so for other spent fuel. In this connection, the storage of spent fuel is also a candidate for multilateral approaches, primarily at the regional level. Storage of special nuclear materials in a few safe and secure facilities will enhance safeguards and physical protection. The IAEA should continue its related efforts and encourage such undertakings. Various countries with state of the art storage facilities in place could move forward and accept spent fuel from others for interim storage. The IAEA could facilitate this arrangement by acting as a "technical inspection agency" assuring the suitability of the facility and applying state-of-the-art safeguards control and inspections.

Combined option: fuel-leasing/fuel take-back

305. In this model, the leasing State will provide the fuel it promised through an arrangement it will separately enter into with its own nuclear fuel "vendor". At the time the government of the leasing State issues an export license to its fuel "vendor" corporation to send fresh fuel to a client reactor, that government will also announce its plan for the management of that fuel once discharged. Without a specific spent fuel management scheme by the leasing State, the lease deal will of course not take place. The leased fuel once removed from the reactor and cooled down,

could either be returned to its country of origin which owns title to it, or, through an IAEA-brokered deal could be sent to a third party State or to a multinational or a regional fuel cycle centre located elsewhere for storage and ultimate disposal.

306. The State obtaining the leased fresh fuel may wish to guarantee having adequate fuel supplies by contracting with more than one government and one international vendor corporation for providing portions of its fuel reloading requirements, under multiple lease deals each covering a portion of its fuel supply needs. In this way it has greater assurance that even if one leasing State and its related "vendor" corporation, for some reason, could not meet all its obligations in a timely manner. In such an event, only a portion of the reload requirements would be affected, and that portion might still be provided by any of its other fresh fuel "vendors" having some spare 'flywheel' capacity. If the State obtaining leased fuel is in good standing with regards to its safeguards obligations (including the Additional Protocol), then it could use the good offices of the IAEA to convince various leasing countries to allow their fuel "vendor" corporations to provide it fuel on lease-take-back arrangements.

307. One weak part in the arrangement outlined above is the willingness, indeed the political capability, of the leasing State to take-back the spent fuel it has provided under the lease contract. It may well be politically difficult for any State to accept spent fuel not coming from its own reactors (that is, reactors producing electricity for the direct benefit of its own citizens). Yet, to make any lease-take-back deal credible, an ironclad guarantee of spent fuel removal from the country where it was used must be provided, otherwise the entire arrangement is moot. In this respect, States with suitable disposal sites, and with grave concerns about proliferation risks, ought to be proactive in putting forward solutions as well as identifying problems and a commitment to forego enrichment and reprocessing in the buyer state should enhance this effort.

308. As an alternative, the IAEA could facilitate the creation of multinational or regional spent fuel storage facilities or of full-fledged fuel cycle centres, where spent fuel owned by leasing States and burned elsewhere could be sent. The IAEA could thus become an active participant in regional spent fuel storage facilities, or third party spent fuel disposal schemes, thereby making lease-take-back fuel supply arrangements more credible propositions.

Other options

309. The concept of "fuel cycle centres" also deserves consideration. Such centres would combine, in one location, several segments of the fuel cycle, e.g. uranium processing and enrichment, fuel fabrication (including MOX), spent fuel storage and reprocessing. Regional fuel cycle centres offer most of the benefits of other MNAs, in particular as to material security and transportation. The further step – the additional co-location of nuclear power plants – would create a genuine "nuclear power park" – an interesting and more long-term concept that deserves further study.

310. In the model of cooperation, one could also foresee the option of companies of different part of the fuel cycle cooperating, and in such a way, supplying a customer with various – or even all – the required services for using nuclear energy.

Chapter 6 - Overarching issues

311. Apart from the cross-cutting factors related to the implementation of MNAs, such as the technical, legal and safeguards factors discussed in Chapter 4 above, there are a number of overarching issues, primarily of a broad political nature, which may have a bearing upon perceptions of the feasibility and desirability of MNAs. These issues may be decisive in any future endeavour to develop, assess and implement such approaches at the national and international level.

Relevant articles of the NPT

312. Cooperation in the peaceful uses of nuclear energy, which had earlier provided the basis for the foundation of the IAEA, is an essential element of the NPT.

313. Article IV.1 of the Treaty provides that nothing shall be interpreted as affecting the "*inalienable right of all Parties to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II*" of the NPT. In accordance with Article IV.2, all Parties to the NPT shall undertake to "*facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy.*" That same paragraph requires that Parties to the Treaty in a position to do so to "*cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of [NNWS Party to the NPT], with due consideration for the needs of the developing areas of the world.*"

314. The Treaty thus explicitly confirmed the inherent right of States to use nuclear energy for peaceful purposes. The commitment by all States parties to cooperate in the further development of nuclear energy and for the NWS to work towards nuclear disarmament was the political bargain that provided the basis for NNWS to abstain from acquiring nuclear weapons. Without the inclusion of Article IV and Article VI, the Treaty would not have been adopted nor received the widespread adherence it obtained afterwards. Article IV was specifically crafted to preclude any attempt to reinterpret the NPT so as to inhibit a country's right to peaceful nuclear technologies - so long as the technology is not used to produce nuclear weapons.

315. NNWS have expressed dissatisfaction about what they increasingly view as a growing imbalance in the NPT: that, through the imposition of restrictions on the supply of materials and equipment of the nuclear fuel cycle by the NWS and the advanced industrial NNWS, those States have backed away from their original guarantee to facilitate the fullest possible exchange referred to in Article IV.2 and to assist NNWS in the development of the applications of nuclear energy. There are also concerns that additional constraints on Article IV might be imposed.

316. Article VI of the Treaty obliges NWS States Parties "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Many NNWS also consider the implementation of Article VI of the NPT by NWS as unsatisfactory, including on entry into force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and on the start of negotiations on a verifiable FM(C)T. Such concerns have fostered a belief among many NNWS that the NPT bargain is being corroded.

Safeguards and export controls

317. Some States have argued that, if the objective of MNAs is merely to strengthen the nuclear non-proliferation regime then, rather than focusing on MNAs, it may be better to concentrate instead on the existing elements of the regime itself, for example, by seeking the universality of the Additional Protocol (AP) to IAEA safeguards agreements and by the universalisation of multilateral export controls, such as that stipulated by UNSC Resolution 1540 (2004), which requires individual States to strengthen their export controls in order to prevent the spread of weapons of mass destruction and related materials to non-State actors.

318. The risks involved in the spread of sensitive nuclear technologies should primarily be addressed by an efficient and cost-effective safeguards system. The IAEA and regional safeguards systems have done an outstanding job in these matters. Safeguards, well and rationally applied, have been the most efficient way to detect and deter further proliferation and to provide States Parties with an opportunity to assure others that they are in conformity with their safeguards commitments. In a related sense, the IAEA safeguards system represents by itself a multilateral approach to non-proliferation. Of course, advances in technologies require safeguards to be strengthened and updated, while protecting commercial, technological and industrial secrets. Therefore the comprehensive safeguards agreement, in the first place, and also the adoption of the Additional Protocol, and its judicious implementation based on State-level risk analysis, are essential steps against further nuclear proliferation.[27] The Additional Protocol has proven to provide additional, necessary and effective verification tools, while protecting legitimate national interests in security and confidentiality. Sustained application of the Additional Protocol in a State can provide credible assurance of the absence of undeclared materials and activities in that State. Together with a comprehensive safeguards agreement, the Additional Protocol should become the de facto safeguards standard.

319. The above notwithstanding, the IAEA should endeavour to further strengthen the implementation of safeguards. For example, it should revisit three facets of its verification system:

a. The technical annexes of the Additional Protocol should be regularly updated to reflect the continuing development of nuclear techniques and technologies.

b. The implementation of the Additional Protocol requires adequate resources and a firm commitment to apply it decisively. It should be recalled that the Model Additional Protocol commits the IAEA not to apply the AP in a mechanistic or systematic way. Therefore the IAEA should allocate its resources on problematic areas rather than on States using the largest amounts of nuclear material.

c. The enforcement mechanisms in case of a fundamental breach of, or in case of non-compliance with the safeguards agreement. Are these mechanisms progressive enough to act as an effective deterrent? Further consideration should be given by the IAEA to appropriate measures to handle various degrees of violations.

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[27] In adopting the model Additional Protocol, the IAEA Board of Governors requested the Director General:

a. to use the Model Protocol as the standard for additional protocols to be concluded by States and other parties to comprehensive safeguards agreements with the IAEA (such protocols to contain all of the measures in the Model Protocol);

b. to negotiate additional protocols or other legally binding agreements with NWS incorporating those measures provided for in the Model Protocol that each NWS has identified as capable of contributing to the non-proliferation and efficiency aims of the Protocol, when implemented with regard to that NWS, and as consistent with that State's obligations under Article I of the NPT;

c. to negotiate additional protocols with other States that are prepared to accept measures provided for in the Model

320. Export guidelines and their implementation are an important line of defence for preventing proliferation. Recent events have shown that criminal networks can find ways around existing controls to supply clandestine activities. Yet, one should remember that all States party to the NPT are obliged, pursuant to Article III.2 thereof, to implement export controls. This obligation was reiterated by Resolution 1540 of the Security Council for all members of the United Nations. Therefore, the participation in the development and implementation of export controls should be broadened, and multilaterally-agreed export controls should be developed in a transparent manner, engaging all States.

321. In fact, the primary technical barriers against proliferation remain the effective and universal implementation of IAEA safeguards under comprehensive safeguards agreements and additional protocols, and the export controls. Both must be as strong as possible on their own merits. MNAs will be complementary mechanisms for strengthening the existing non-proliferation regime.

Voluntary participation in MNAs versus a binding norm

322. The present legal framework does not oblige countries to participate in MNAs; the political environment makes it unlikely that such a norm can be established any time soon. Establishing MNAs resting on ***voluntary*** participation is thus the more promising way to proceed. In a voluntary arrangement covering assurances of supply, recipient countries would, for the duration of the respective supply contract, renounce the construction and operation of sensitive fuel cycle facilities and accept safeguards of the highest current standards, including comprehensive safeguards and the Additional Protocol. Where the demarcation line between permitted R&D activities and renounced development and construction activities has to be drawn is a matter for further consideration. In voluntary MNAs involving facilities, the participating countries would presumably commit to carry out the related activities solely under the common MNA roof.

323. In reality, countries will enter into such multilateral arrangements according to the economic and political incentives and disincentives offered by these arrangements. A political environment of mutual trust and consensus among the partners - based on full compliance with the agreed nuclear non-proliferation obligations of the partners - will be necessary to the successful negotiation, creation and operation of an MNA.

324. Beyond this, a new ***binding*** international norm stipulating that sensitive fuel cycle activities are to be conducted exclusively in the context of MNAs and no longer as a national undertaking would amount to a change in the scope of Article IV of the NPT. The wording and negotiation history of this article emphasise the right of each party in good standing to choose its national fuel cycle on the basis of its sovereign consideration. This right is not independent of the faithful abiding by the undertakings under Articles I and II. But if this condition is met, no legal barrier stands in the way of each State party to pursue all fuel cycle activities on a national basis. Waiving this right would thus change the "bargain" of the NPT.

325. Such a fundamental change is not impossible if the parties were to agree on it in a broader negotiating frame. For NNWS, such a new bargain can probably only be realised through universal principles, applying to all States, and with additional steps by NWS regarding nuclear disarmament. In addition, a verifiable FM(C)T might also be one of the preconditions for binding multilateral obligations. As such a treaty would terminate the right of any participating nuclear weapon States and non-NPT parties to run reprocessing and enrichment facilities for nuclear explosive purposes, it would bring them to the same level – with regard to such activities – as non-nuclear weapon States. The new restrictions would apply to all States and facilities related to the technologies involved, without exception. At that time, multilateral arrangements could become a

universal, binding principle. The question may also raised as to what might be the conditions required by NWS and non-NPT States to commit to binding MNAs involving themselves.

Nuclear-weapon States and non-NPT States

Weapon-usable material (stocks and flows) and sensitive facilities that are capable of producing such material are located predominantly in the NWS and non-NPT States. While the issue discussed in previous chapters raised a concern about the construction of such facilities in NNWS in the context of an MNA, the question here is how MNAs for existing or future sensitive facilities should include NWS and non-NPT States, in light of the possibility that the nuclear material produced therefrom could contribute to such a State's nuclear weapons programme. This shows again the relevance of a FM(C)T.

326. The feasibility of bringing NWS and non-NPT States into MNAs should indeed be considered at an early stage. As long as MNAs remain voluntary, nothing would preclude such States from participating in an MNA. In fact, France (in connection with the EURODIF arrangement) and the United Kingdom (in connection with Urenco) are examples of such participation. In transforming existing civilian facilities into MNAs subject to safeguards and security requirements, such States would demonstrate their support for non-proliferation and for peaceful international nuclear collaboration. If NPT and non-NPT States were both to participate in the same MNA, this would require a change in policy on the part of the participating NPT States Parties.

Breakout and other risks

327. Whether voluntary or compulsory, multilateral facilities share a potential weakness with their national counterparts, namely the risk of the host country "breaking out": for example, by creating a political emergency, expelling multinational staff, withdrawing from the NPT (and thereby terminating its safeguards agreement), and operating the multilateral facility without international control. For multilateral facilities to be acceptable, this risk would need to be addressed. Nevertheless, MNAs offer a better protection than national facilities if they are run by multinational staff and involving intertwined activities. At a minimum, such breakout would alienate the other partners in the MNA, possibly lead to some retaliatory measures, raise political temperatures and give the international community (and the IAEA) advance notice that things might be amiss - hopefully within the 3 months necessary to do something about it. As a further disincentive to breakout, NPT States Parties desiring to host or participate in the MNA, could choose to forego their rights under Article X.1 of the Treaty, or to allow continuation of safeguards and/or to commit to returning equipment and materials obtained through MNA participation.

328. The United Nations Security Council, as the international organ bearing the main responsibility for the maintenance of international peace and security, should be prepared to respond to such action, insofar as withdrawal from the NPT could be seen as a threat to international peace and security.

329. Breaking out of the NPT would be a clear challenge to the non-proliferation regime and to the security of the international community. However, several other proliferation scenarios more specifically related to the concept of MNA should be included in any agreement setting up an MNA. One is the possibility of withdrawal from the MNA (that is to say, "going national"), without leaving the NPT. A second would entail the misuse of technology by non-host parties to the MNA on their own territory using know-how acquired through the MNA.

Enforcement

330. Eventually, the success of all efforts to improve the nuclear non-proliferation regime depends upon the effectiveness of compliance and enforcement mechanisms. Enforcement measures in case of non-compliance can be partially improved by MNAs' legal provisions, which will carefully specify a definition of what constitutes a violation, by whom such violations will be judged, and possible measures that could be directly applied by the partners in addition to broader political tools.

331. However, enhanced safeguards, MNAs, or new undertakings by States will not serve their full purpose if the international community does not respond with determination to serious cases of non-compliance, be it diversion, clandestine activities or breakout. Responses are needed at four levels, depending upon the specific case: the MNA partners of the non-compliant State; the IAEA; the States Parties to the NPT; and the UN Security Council. Where they do not currently exist, appropriate procedures and measures must be available and must be made use of at all four levels to cope with non-compliance instances, stressing that States violating important treaties and arrangements should not be permitted to do so unimpeded.

Chapter 7 - Multilateral nuclear approaches: the future

332. As noted in Chapter 3, past initiatives for multilateral nuclear cooperation did not result in any tangible results. Proliferation concerns were perceived as not serious enough. Economic incentives were seldom strong enough, and concerns about assurances of supply were paramount. National pride also played a role, alongside expectations about the technological and economic spin-offs to be derived from nuclear activities. Many of those considerations may still be pertinent today. However, the result of balancing those considerations today, in the face of a possible expansion of nuclear facilities over the next decades and the potential for increasing proliferation dangers may well produce a political environment more conducive to MNAs in the 21st century.

333. The potential benefits of MNAs for the non-proliferation regime are both symbolic and practical. As a confidence-building measure, multilateral approaches have the potential to provide enhanced assurance to the partners and to the international community that the most sensitive parts of the civilian nuclear fuel cycle are less vulnerable to misuse for weapon purposes. Joint facilities with multinational staff put all MNA participants under a greater degree of scrutiny from peers and partners and may also constitute an obstacle against breakout by the host partner. MNAs will also reduce the number of sites where sensitive facilities are operated, thereby curbing proliferation risks; and they diminish the number of potential points of access for non-state actors to sensitive material. Moreover, these approaches also have the potential to facilitate the continued use of nuclear energy for peaceful purposes and enhance the prospects for the safe and environmentally sound storage and disposal of spent nuclear fuel and radioactive waste.

334. Multilateral approaches could also provide the benefits of cost-effectiveness and economies of scale for smaller countries or those with limited resources, while ensuring the benefits of the use of nuclear technology. Similar benefits have been derived in the context of other high technology sector, such as aviation and aerospace.

335. However, the case to be made in favour of MNAs is not entirely straightforward. States with differing levels of technology, different degrees of institutionalisation, economic development and resources and competing political considerations may not all reach the same conclusions as to the benefits, convenience and desirability of MNAs. Some might argue that multilateral approaches point to the loss or limitation of State sovereignty and independent ownership and control of a key technology sector, leaving unfairly the commercial benefits of these technologies to just a few countries. Others might argue that multilateral approaches could lead to further dissemination of, or loss of control over, sensitive nuclear technologies, and result in higher proliferation risks.

336. One of the most critical steps is to devise effective mechanisms for assurances of supply of material and services, which are commercially competitive, free of monopolies and free of political constraints. Effective assurances of supply will have to include back-up sources of supply in the event that an MNA supplier is unable to provide the required material or services. In this context, the IAEA could play a pivotal role as a kind of guarantor in an international mechanism for emergency supply.

337. Appropriate organisational and institutional arrangements, as well as the relevant legal instruments, would need to be developed, both at the State level and at the commercial level. Arrangements at the State or governmental level would need to specify, for example, the safeguards obligations and the degree of restraint on parallel national nuclear fuel cycle activities in participating States. At the commercial level, such matters as the allocation of ownership, financial obligations and facility operation would need to be articulated.

338. It is also important that international oversight of an MNA be arranged, as needed, to achieve confidence of partners on adequate safety and physical security of the proposed facility.

339. In summary, the Expert Group on Multilateral Approaches for the Nuclear Fuel Cycle has reviewed the various aspects of the fuel cycle, identified a number of options for MNAs deserving of further consideration, and noted a number of pros and cons for each of the options. It is hoped that the report of the Expert Group will serve as a building block, or as a milestone. It is not intended to mark the end of the road. MNAs offer a potentially useful contribution to meeting prevailing concerns about assurances of supply and non-proliferation.

340. In the meantime, the Group recommends that steps be taken to strengthen overall controls on the nuclear fuel cycle and the transfer of technology, including safeguards and export controls: the former by promoting adherence to Additional Protocols, the latter through a more stringent implementation of guidelines and universal participation in their development.

341. In order to maintain momentum, the Group recommends that attention be given – by the IAEA Member States, by the IAEA itself, by the nuclear industry and by other nuclear organisations – to multilateral nuclear approaches in general and to the **five approaches** suggested below in particular.

Five suggested approaches

The objective of increasing non-proliferation assurances concerning the civilian nuclear fuel cycles, while preserving assurances of supply and services around the world could be achieved through a set of gradually introduced multilateral nuclear approaches (MNA):

Reinforcing **existing commercial market mechanisms** on a case-by-case basis through long-term contracts and transparent suppliers' arrangements with government backing. Examples would be: fuel leasing and fuel take-back, commercial offers to store and dispose of spent fuel and commercial fuel banks.

Developing and implementing **international supply guarantees** with IAEA participation. Different models should be investigated, notably with the **IAEA as guarantor** of service supplies, e.g. as administrator of a fuel bank.

Promoting voluntary conversion of **existing facilities to MNAs**, and pursuing them as **confidence-building measures**, with the participation of NPT non-nuclear weapon States and nuclear weapon States, and non-NPT States.

Creating, through voluntary agreements and contracts, **multinational, and in particular regional, MNAs for new facilities** based on joint ownership, drawing rights or co-management for front-end and back-end nuclear facilities, such as uranium enrichment; fuel reprocessing; disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.

The scenario of a further expansion of nuclear energy around the world might call for the development of a **nuclear fuel cycle with stronger multilateral arrangements** – by region or by continent - **and broader cooperation**, involving the IAEA and the international community.

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Annex 1 – Letter from the Director General

11 June 2004

Dear Mr. ....

As an expert on nuclear fuel cycle and non-proliferation matters, you will have followed the recent international discussions about the need to further strengthen the nuclear non-proliferation regime. Some of the proposals and initiatives in this regard focus on the non-proliferation benefits of more effective controls over the most proliferation sensitive technologies involved in the nuclear fuel cycle – such as enrichment and reprocessing.

During the March 2004 meeting of the Agency's Board of Governors, I signaled my intention to convene a group of experts to explore options and develop proposals for improved controls, including possible multilateral oversight arrangements, for the front- and the back-ends of the nuclear fuel cycle. In my view, the work of such a group will be an important contribution to the ongoing debate on this issue. Moreover, I expect that this work may result in practical proposals, which, if implemented, could provide enhanced assurance to the international community that sensitive portions of the nuclear fuel cycle are less vulnerable to misuse for proliferation purposes and thereby facilitate the continued uses of nuclear energy for peaceful purposes.

Following consultations, and in recognition of your knowledge and expertise, I am pleased to invite you to participate in a personal capacity in the work of the International Expert Group which I am setting up with the task of preparing an initial study on the above issues by Spring 2005. I trust you will be able to accept this invitation and will also be able to arrange for the necessary funding of your participation.

I have invited Mr. Bruno Pellaud, former Deputy Director General of the Agency for safeguards and verification, to be the Chairman of the Expert Group. Based on discussions with him, I suggest that the first meeting of the group be held from 30 August to 3 September 2004 in Vienna at the Agency's Headquarters. It is anticipated that the Group will have up to four meetings in Vienna in order to complete its work.

The Terms of Reference for the Group are attached. I have asked Mr. Pellaud to contact you with more details and information relating to the arrangements for the meetings of the Group.

Yours sincerely,

Mohamed ElBaradei (*signed*)

Terms of Reference:

a. Identify and provide an analysis of issues and options relevant to multilateral approaches to the front-end and back-end of the nuclear fuel cycle;

b. Provide an overview of the policy, legal, security, economic and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and

c. Provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

Annex 2 - Participants and contributors

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Annex 3 - Acronyms

^{235}U	Uranium 235
^{238}U	Uranium 238
AP	Additional Protocol (IAEA INFCIRC/540(Corr.))
BNFL	British Nuclear Fuels Limited
CAS	Committee on Assurances of Supply (1980-1987)
CPPNM	Convention on the Physical Protection of Nuclear Material (1980)
CTBT	Comprehensive Nuclear-Test-Ban Treaty
DIV	Design information verification
DPRK	Democratic People's Republic of Korea
EC	European Commission
EMIS	Electro-Magnetic Isotope Separation
EU	European Union
EURATOM	European Atomic Energy Community
EURODIF	Usine EUROpéenne d'enrichissement par DIFfusion gazeuse (European Gaseous Diffusion Uranium Enrichment Consortium)
FM(C)T	Fissile Material (Cut-Off) Treaty
FORATOM	European Atomic Forum
GDP	Gaseous Diffusion Plant
HEU	High Enriched Uranium ($^{235}U \geq 20\%$)
HLW	High Level Waste
HQ	Headquarters
IAEA	International Atomic Energy Agency
INFCE	International Nuclear Fuel Cycle Evaluation (1977-1980)
INFCIRC	Information Circular
INMS	International Nuclear Material Storage
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles (2000-....)
IPS	(Expert Group on) International Plutonium Storage (1978-1982)
IT	Information Technology
JNC	Japan Nuclear Cycle Development Institute
kWh	Kilowatt-hours
LES	Louisiana Enrichment Services
LEU	Low Enriched Uranium ($^{235}U < 20\%$)
LFUA	Limited Frequency Unannounced Access
LWR	Light Water Reactor

MNA(s)	Multilateral Nuclear Approaches
MOX	Mixed Oxide (mixture of the oxides of uranium and plutonium used as reactor fuel)
MPC&A	Material, Protection, Control and Accounting
MWe	Megawatt electrical
NEA	Nuclear Energy Agency (specialized agency within the OECD)
NNWS	Non-Nuclear-Weapon State
NPT	Non Proliferation Treaty
NSG	Nuclear Suppliers' Group
NWS	Nuclear-Weapon-State under the NPT
OECD	Organization for Economic Cooperation and Development
Pu	Plutonium
PuO_2	Plutonium di-oxide
PUREX	Plutonium and Uranium recovery by extraction
PWR	Pressurized Water Reactor
R&D	Research and Development
REU	Recycled Uranium
RFCC	Regional Nuclear Fuel Cycle Centres (1975-1977)
SAGOR	Program for Development of Safeguards for the Final Disposal of Spent Fuel in Geologic Repositories (1994-1998)
SAGSI	Standing Advisory Group on Safeguards Implementation
SAPIERR	Support Action: Pilot Initiative on European Regional Repositories (5.4)
SQ	Significant Quantity
SSAC	State System of Accounting for and Control of nuclear material
SWU	Separative Work Unit (Measure for the capacity of an enrichment plant)
TBP	Tributyl phosphate
TECDOC	IAEA Technical Document
TENEX	Techsnabexport
tHM/a	Tonnes heavy Metal per year
THOREX	Thorium recovery by extraction
U	Uranium
U_3O_8	Tri-uranium oxide
UF_6	Uranium hexa-fluoride
UN	United Nations
UNCPICPUNE	United Nations Conference for the Promotion of International Cooperation in the Peaceful Uses of Nuclear Energy (1987)
UNIREP	United Reprocessors Gesellschaft

UNSC	United Nations Security Council
UO_2	Uranium di-oxide
UO_3	Uranium tri-oxide
Urenco	Uranium Enrichment Company
USEC	United States Enrichment Corporation
WWER	Water cooled, water moderated power reactor

For further information see the "IAEA Safeguards Glossary"